DEC STD 122-0 AC Power Line Standard: Design Requirements and Guidelines

DOCUMENT IDENTIFIER: A-DS-EL00122-00-0000 Rev J, 20-May-1992

ABSTRACT: This standard provides design requirements and guidelines for power supplies, power control equipment, and other devices that operate from primary ac power.

APPLICABILITY: This document is mandatory for all personnel involved with the design and development of new computer products marketed by Digital that use any of the following types of equipment and components requiring primary ac power: power supplies, power control equipment, rotating equipment, such as blowers, fans, motors, and distribution components, such as ac power cables, line filters, contactors, circuit breakers, and connectors.

STATUS: APPROVED 20-May-1992; use VTX SMC for current status.

This document is confidential and proprietary, and is the property of Digital Equipment Corporation. It is an unpublished work protected under applicable copyright laws.

© Digital Equipment Corporation. 1989, 1992. All rights reserved.

DEC STD 122-0 AC Power Line Standard: Design Requirements and Guidelines

DOCUMENT IDENTIFIER: A-DS-EL00122-00-0000 Rev J, 20-May-1992

REVISION HISTORY:	Rev A,	02-Aug-1975	
	Rev B,	15-Apr-1976	ECO Number MLO01
	Rev C,	30-Oct-1981	ECO Number MLO02
	Rev D,	17-Dec-1981	ECO Number MLO03
	Rev E,	18-Aug-1983	ECO Number APO04
	Rev F,	13-Feb-1986	ECO Number LJO05
	Rev H,	13-Feb-1989	ECO Number CTS07
	Rev H1,	10-Aug-1990	ECO Number CTS08
	Rev J,	20-May-1992	ECO Number NRO09

Document Management Category: AC Power Requirements and Entry (HRP)
Responsible Department: Power Systems Engineering (PSE)
Responsible Person: Francis A. Loya

APPROVAL: This document has been reviewed and recommended for approval by the General Review group for its category and the DEC STD 122-0 Advisory Committee.

Francis A. Loya - Low End Systems Power Electronics

Eric Williams - Standards Process Manager

Direct requests for further information to:

Francis A. Loya
Use $ VTX ELF for the latest location information.

Use VTX SMC to order copies of this document from Standards and Methods Control. Send distribution questions to JOKUR::SMC or call DTN: 234-4423.

The DIGITAL logo is a trademark of Digital Equipment Corporation.

CONTENTS

1 INTRODUCTION 1
1.1 PURPOSE 1
1.2 SCOPE 1
1.3 AC POWER TESTING 1
2 DEFINITIONS OF TERMS 2
2.1 STEADY STATE INPUT CURRENT (RMS) 2
2.2 APPARENT POWER (VOLT-AMPERES) 2
2.3 REAL POWER (WATTS) 2
2.4 POWER FACTORS 3
2.4.1 Displacement Power Factor 3
2.4.2 Total Power Factor 3
2.4.3 Start-up Power Factor 3
2.5 INRUSH CURRENT 3
2.6 INITIAL INRUSH CURRENT 4
2.7 RESTART INRUSH CURRENT 4
2.8 START-UP CURRENT 4
2.9 CURRENT UNBALANCE 4
2.10 NOMINAL VOLTAGE (AC) 4
2.11 VOLTAGE DEVIATION FACTOR 4
2.12 VOLTAGE UNBALANCE 5
2.13 POWER LINE DISTURBANCE 6
2.13.1 Impulse 6
2.13.2 Oscillatory Decaying 6
2.13.3 Voltage Sag 6
2.13.4 Voltage Surge 6
2.13.5 Voltage Outage 7
2.13.6 Brownout 7
2.14 HARMONIC 7
2.15 DISTORTION FACTOR 7
2.15.1 Voltage Distortion Factor 7
2.15.2 Current Distortion Factor 7
2.16 CREST FACTOR (CURRENT OR VOLTAGE) 7
2.17 AC POWER SOURCE REFERENCE IMPEDANCE 8
2.18 NEUTRAL CONDUCTOR 9
2.19 NEUTRAL CURRENT 9
2.20 PRIMARY AC POWER SOURCE 9
2.20.1 European Power Systems 10
2.20.1.1 TT System 10
2.20.1.2 IT System 10
2.20.1.3 TN System 11
2.21 RIDE-THROUGH 12
2.22 RIDE-THROUGH TIME 12
2.23 HOLD-UP 12

2.24 HOLD-UP TIME 12
2.25 RIDE-THROUGH TIME/HOLD-UP TIME RELATIONSHIP 13
2.26 PHASE ROTATION 14

3 GENERAL INFORMATION 14

4 DESIGN REQUIREMENTS 15
4.1 VOLTAGE AND FREQUENCY NOMINALS 15
4.2 RECOMMENDED SYSTEM OPERATING VOLTAGE AND FREQUENCY RANGE 17
4.2.1 System Start-up Voltage 18
4.2.2 Power Quality 18
4.2.3 Design and Test Ranges for Power Products Using AC Power 19
4.3 VOLTAGE VARIATION: DYNAMIC 20
4.4 FREQUENCY VARIATIONS: STEADY STATE 20
4.5 PHASE ANGLE UNBALANCE 20
4.6 VOLTAGE UNBALANCE 20
4.7 UNDERVOLTAGES AND OUTAGES 20
4.8 OVERVOLTAGE 20
4.9 INRUSH CURRENT 21
4.9.1 Inrush Current Limits 21
4.9.2 Restart Inrush Current 22
4.10 HIGH VOLTAGE TRANSIENTS 22
4.10.1 Equipment Transient Voltage Requirements 23
4.10.1.1 Equipment Survival Limits 24
4.10.1.2 Equipment Performance Susceptibility Limits 24
4.10.1.3 Ring Wave and Impulse Waveforms 25
4.10.2 Application of Survival Limit Waveforms 26
4.10.2.1 Level A Survival Testing—Single-Phase Devices 27
4.10.2.2 Level B and Level C Survival Testing—Single-Phase Devices 28
4.10.2.3 Level B and Level C Survival Testing—Three-Phase Devices. 28
4.10.3 Application of Performance Susceptibility Waveforms 29
4.10.3.1 Level A Performance Susceptibility Testing—Single-Phase Devices 29
4.10.3.2 Level B and Level C Performance Susceptibility Testing—Single-Phase Devices 30
4.10.3.3 Level B and Level C Performance Susceptibility Testing—Three-Phase Devices 30
4.11 EQUIPMENT-GENERATED VOLTAGE TRANSIENTS 31
4.12 EQUIPMENT SAFETY 31
4.13 HOLD-UP TIME 31
4.14 PHASE ROTATION SENSITIVE LOADS 31
4.15 VOLTAGE CREST FACTOR 32
4.16 DIRECT CURRENT LIMITATIONS IN AC INPUT POWER CIRCUITS 32
4.16.1 Requirements 32

5 DESIGN GUIDELINES 33

5.1 AC DISTRIBUTION 33
5.1.1 Three-Phase Star (Wye) 33
5.1.2 Two-Phase Star (Wye) 33
5.1.3 Three-Phase Delta 34
5.1.4 Three-Phase Open Delta 34
5.1.5 Single-Phase 34
5.2 SINGLE-PHASE LOADS 35
5.3 BLOWERS AND FANS 35
5.4 CIRCUIT BREAKERS 35
5.5 POWER CORDS AND CORD SETS 35
5.6 AC WIRING 35
5.7 FREQUENCY CHANGES 35
5.8 AC MOTORS 36
5.9 CONSTANT VOLTAGE TRANSFORMERS 36
5.10 VOLTAGE CHANGES 36
5.11 PHASE BALANCING 36
5.12 LEAKAGE CURRENT 37
5.13 INTERPHASE CURRENT UNBALANCE FOR CONFIGURED SYSTEMS 37
5.14 POWER REQUIREMENTS IN GIA 37
5.15 SINGLE-PHASE POWER LIMITATIONS FOR VARIOUS COUNTRIES 38
5.16 CONNECTING OF 120-VOLT FANS AND BLOWERS FOR 120 V OR 240 V POWER 38
5.17 MASS STORAGE DEVICES 39
5.18 OPERATION IN JAPAN AND AUSTRALIA (WESTERN) 39
5.19 EFFECTS OF DIRECT CURRENT IN AC INPUT POWER CIRCUITS 39
5.20 COMPUTER VOLTAGE SUSCEPTIBILITY PROFILE 40
5.21 VOLTAGE WAVEFORM DISTORTION 41

Appendix A REFERENCED DOCUMENTS 57

A.1 EL-Class Digital Documents 57

A.2 Other Documents 57

A.3 Ordering Information 57

FIGURES

1 Reference Network 8
2 TT System 10
3 IT System 11
4 TN System 11
5 Ride-Through Time/Hold-Up Time Relationship 13
6 Disturbance/Time-Duration Computer Susceptibility Profile (Information from CBEMA ESC-3 Power Interface Subcommittee, 1978) 40

TABLES

1 Common Voltages and Frequencies in Major Market Areas 16
2 Recommended System Operating Voltage and Frequency Range 17
3 Voltage and Frequency Design Ranges 19
4 Equipment Survival Limits 24
5 Equipment Performance Susceptibility Limits 25
6 Single-Phase Power Limitations for Various Countries 38
7 Input Current Harmonics 42
8 AC Power Characteristics of Various Countries and Market Areas 43

1 INTRODUCTION

This standard provides equipment designers with information concerning ac power characteristics that can be expected to be provided by major power utilities.

1.1 PURPOSE

This standard provides a set of design requirements and design aids to:

a. Assist in avoiding problems that might result from neglecting consideration of specific conditions affecting the performance of computer equipment.

b. Ensure equipment can operate satisfactorily in all Digital market areas.

1.2 SCOPE

This standard describes the corporate policy, design requirements, and design guidelines for all new computer products marketed by Digital that use any of the following types of equipment and components requiring primary ac power whether designed by Digital or a third party:

- Power supplies
- Power conditioning equipment
- Uninterruptable power system (UPS)
- Power control equipment
- Rotating equipment such as blowers, fans, and motors
- Distribution components such as ac power cables, line filters, contactors, circuit breakers, and connectors

Compliance with this standard implies that the design of the product meets the requirements of the relevant sections within head 4. It is the responsibility of the equipment designer to ascertain compliance by conducting appropriate tests. This responsibility is in keeping with Digital's policy to design and manufacture reliable products.

Noncompliance to any design criteria specified in head 4 requires a waiver. Refer to *DEC STD 066-2 Waivers to Digital Design Standards* for more information.

1.3 AC POWER TESTING

All products and equipment that use primary ac power shall be tested in order to have their input ac power described by the following minimum characteristics. These ac input power characteristics shall be included in the product's engineering specification.

- Input voltage(s) in volts root mean square (rms)
- Input current(s) and neutral current in amperes rms
- Input volt-amperes
- Input real power (watts)
- Input power factor
- Initial inrush current and restart inrush current

- Start-up current and duration (if applicable)
- Ride-through time (if applicable)
- Hold-up time (if applicable)
- Crest factors of line currents
- Input line transient immunity
- Input line current harmonics up to the 40th

For ac test methods and instrumentation, refer to *DEC STD 122-1 AC Power Line Standard—Measurement of AC Power Parameters*.

2 DEFINITIONS OF TERMS

The following subheads define the terms used in this document.

2.1 STEADY STATE INPUT CURRENT (RMS)

The steady state input current is the rms value of current drawn by the load at the nominal rated input voltage and where the current does not vary by more than ±10% over any 10-second period of normal specified operation.

2.2 APPARENT POWER (VOLT-AMPERES)

The apparent power is the product of the steady state rms values of voltage and current.

a. Mathematically, the apparent power is given by the equation:

$$Pa = EI$$

$$Pa = \sqrt{(E_1^2 + E_2^2 + \ \ldots + E_n^2)\ \ (I_1^2 + I_2^2 + \ \ldots \ + I_n^2)}$$

Where E and I are the rms amplitude of the voltage and current, respectively; E_n and I_n are the rms amplitudes of the nth harmonic of voltage and current, respectively.

b. The arithmetic summation of steady state volt-amperes of several devices is not valid unless the input characteristics of each are identical (harmonic content, waveform, phase, and so forth.)

2.3 REAL POWER (WATTS)

The real power is the sum of the products of the in-phase components of the voltage and current for each order of the harmonic components.

It is the time average of the values of the instantaneous power; the average being taken over one period of the waveform.

NOTE

Mathematically, the real power Pr is given by the equation:

$$Pr = \frac{1}{T} \int_{to-T/2}^{to+T/2} p \ dt$$

Where T is the period of the waveform and p is the instantaneous power.

2.4 POWER FACTORS

The following subheads define types of power factors.

2.4.1 Displacement Power Factor

The displacement power factor is the ratio of the real power of the fundamental wave in watts to the apparent power of the fundamental wave in volt-amperes.

2.4.2 Total Power Factor

The total power factor is the ratio of the total input real power (watts) to the total input apparent power (volt-amperes).

NOTE

This definition includes the effect of harmonic components of the current and voltage and the effect of the phase displacement between the current and voltage.

The total power factor is determined as:

$$p.f. = \frac{\int_{to-T/2}^{to+T/2} vi \ dt}{\left[\int_{to-T/2}^{to+T/2} v^2 \ dt \ \times \ \int_{to-T/2}^{to+T/2} i^2 \ dt \right]^{1/2}}$$

where T is the period of the waveform.

2.4.3 Start-up Power Factor

The start-up power factor is the power factor during the initial start-up beginning after the inrush period (first cycle) and extending for the duration of the start-up current. The duration of the start-up power factor must be specified in the engineering specification. This characteristic is usually related to large motors that have significant start-up currents.

2.5 INRUSH CURRENT

The inrush current is the current occurring during the time interval equivalent to one period of the power line frequency when the voltage is first applied. This characteristic is always specified as the peak (not rms) value of the inrush current waveform.

2.6 INITIAL INRUSH CURRENT

The initial inrush current is the current that occurs upon the application of power when any inrush limiting device or circuit, if used, provides maximum inrush current limiting.

2.7 RESTART INRUSH CURRENT

Restart inrush current is the current that occurs upon the re-application of power when any inrush current-limiting device or circuit, if used, does not provide maximum current limiting because it is not fully reset. This definition is applicable in situations of rapid on/off cycling of input power, or during short outages of input power.

2.8 START-UP CURRENT

The start-up current is that current which occurs after the inrush and continuing until the current is within 10% of the steady state value.

2.9 CURRENT UNBALANCE

$$Unbalance\ percent = \frac{(I\ max - I\ min)\ \times 100}{(I\ avg)}$$

I max = maximum line current in rms amperes
I min = minimum line current in rms amperes

$$I\ avg = \frac{(I_A + I_B + I_C)}{3}$$

I_A, I_B, I_C = line currents in rms amperes

2.10 NOMINAL VOLTAGE (AC)

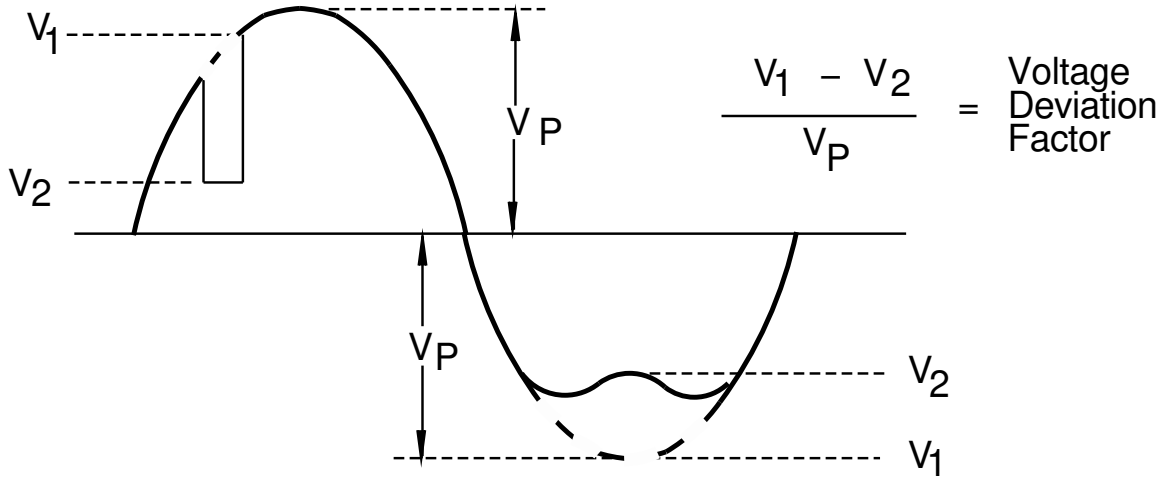
A nominal value assigned to the circuit or system for the purpose of conveniently designating a voltage distribution system. The term *nominal voltage* designates not a single voltage, but a range of voltages over which the actual voltage at any point on the circuit or system may vary and still provide satisfactory operation of equipment connected to the system.

2.11 VOLTAGE DEVIATION FACTOR

The voltage deviation factor is the ratio of the maximum difference between the corresponding ordinate of the wave to the maximum ordinate of the equivalent sine wave when the waves are superimposed in such a way as to make this maximum difference as small as possible.

NOTE

The equivalent sine wave is defined as having the same frequency and the same rms voltage as the wave being tested.



2.12 VOLTAGE UNBALANCE

$$Unbalance\ percent = \frac{(V\ max - V\ min)\ \times 100}{(V\ avg)}$$

V max = maximum line-to-line rms voltage
V min = minimum line-to-line rms voltage

$$V\ avg = \frac{V_{AB} + V_{BC} + V_{CA}}{3}$$

V_{AB}, V_{BC}, V_{CA} = line-to-line voltage

NOTE

The expression

$$(V\ max - V\ avg)\ \times 100/(V\ avg)$$

or

$$(V\ avg - V\ min)\ \times 100/(V\ avg)$$

always yields a lower percentage unbalance than the first expression in subhead 2.12.

Also for any specific unbalance condition,

$$\frac{(V\ max - V\ avg)}{(V\ avg)}$$

can yield a higher or lower value than when:

$$\frac{(V\ avg - V\ min)}{(V\ avg)}$$

is used.

2.13 POWER LINE DISTURBANCE

A power line disturbance is any fluctuation of the power line voltage that exceeds its specified steady state limits. Power line voltage disturbances may be classified into the following categories:

2.13.1 Impulse

An impulse is a sudden disturbance of unidirectional polarity in the power line voltage. Impulses may be either spikes or notches.

A spike is defined as an increase from the ideal power-frequency line wave having a duration that is short when compared with one cycle of the line frequency. Characteristically, spikes have a duration of less than a microsecond to a few milliseconds.

A notch is defined as a momentary dip in supply voltage caused by the reactive drop in the supply circuit during high rates of change in currents occurring in the ac lines. Durations of less than a microsecond to a few milliseconds may typically be encountered.

2.13.2 Oscillatory Decaying

Oscillatory decaying transients have a frequency range from 200 Hz to 5 kHz or more, with a beginning amplitude of up to 100% or more of nominal peak voltage. These types of transients usually result from power factor correction capacitors switching and other network or load switching.

2.13.3 Voltage Sag

A voltage sag or dip is a momentary undervoltage below steady state low line limit that persists for at least a substantial part of one cycle (and usually for a few hundreds of cycles) of the line frequency.

NOTE

The voltage sag or spike is the most common cause of power-related computer system problems. It is most often caused by system power faults, large load changes, and utility equipment malfunction.

2.13.4 Voltage Surge

A voltage surge is a momentary overvoltage above the steady state high-line limit that persists for at least a substantial part of one cycle (and usually for a few hundreds of cycles) of the line frequency.

2.13.5 Voltage Outage

A voltage outage is a condition resulting from system power faults and utility equipment malfunctions, where the voltage may depress to less than 25% of nominal and with range of duration from one cycle to seconds if automatic correction is made, from minutes to several hours if manual correction is made, and for days for power system and utility equipment damage.

2.13.6 Brownout

A brownout is a planned reduction in voltage put in effect by utilities when the demand for power exceeds their generating capacity. A typical brownout is a reduction of voltage by 3% and, if necessary, an additional 2%. In severe cases, there is a third reduction of an additional 3%.

2.14 HARMONIC

A harmonic is a sinusoidal component of a periodic wave having a frequency that is an integral multiple of the fundamental frequency. For example, a component whose frequency is three times the fundamental is called a third harmonic.

2.15 DISTORTION FACTOR

The distortion factor is used to define the effect of harmonics on the power system voltage. It is defined as the ratio, expressed as a percent, of the square root of the sum of the squares of the rms value of the harmonics to the rms value of the fundamental.

2.15.1 Voltage Distortion Factor

The ratio, expressed as a percent, of the square root of the sum of the squares of the rms value of all the voltage harmonics to the rms value of the fundamental voltage.

$$V_{DF} = \frac{\sqrt{(E_2^2 + E_3^2 + E_4^2 + E_5^2 + \ldots)}}{E_1} \times 100$$

2.15.2 Current Distortion Factor

The ratio, expressed as a percent of the square root of the sum of the squares of the rms value of all the current harmonics to the rms value of the fundamental current.

$$I_{DF} = \frac{\sqrt{(I_2^2 + I_3^2 + I_4^2 + I_5^2 + \ldots)}}{I_1} \times 100$$

2.16 CREST FACTOR (CURRENT OR VOLTAGE)

The crest factor is the ratio of the maximum (peak value) to the rms value of the waveform.

2.17 AC POWER SOURCE REFERENCE IMPEDANCE

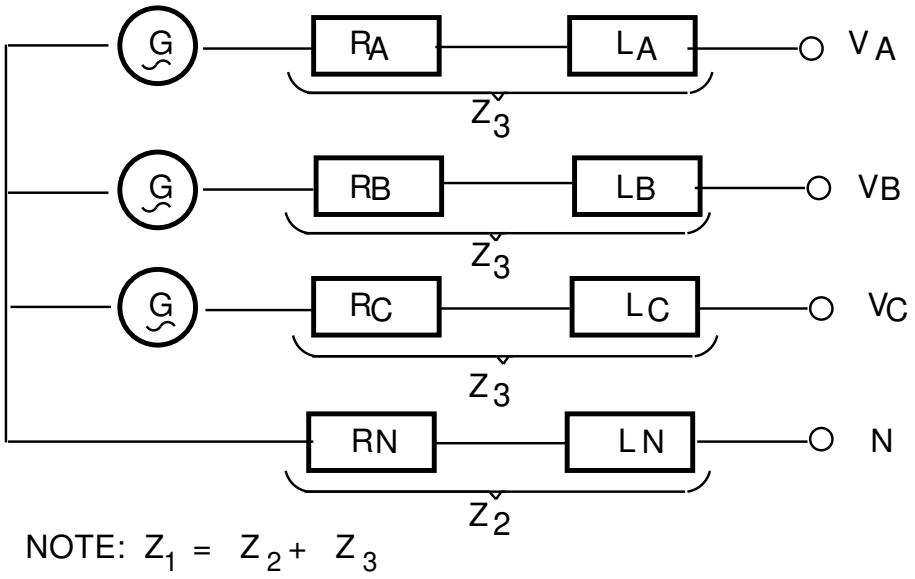
The magnitude of the voltage distortion on the network depends directly on the local characteristics and impedances of the network, as seen from the point of connection of the utilization equipment.

In order to determine how equipment that generates harmonic currents affects the network, it is necessary to know the source impedance over a frequency range from the fundamental to some upper limit, typically 2500 Hz.

The impedance is a complex relationship between the inductive and capacitive reactances; it varies widely from location to location within a network; and is difficult to calculate and measure.

Provisionally, for the purposes of calculating the voltage distortion factor, the source impedance will be assumed to be resistance and pure inductance in series as shown in Figure 1. The following values given for the fundamental frequency impedances apply to utility distribution networks. Distribution networks sourced from motor-generators or other auxiliary power sources may exhibit impedances higher than those given.

Figure 1: Reference Network



For loads up to 1.4 kVA per phase:

Phase to neutral	Z1 = (0.40 + jw0.79E^{-3}) ohms
Neutral	Z2 = (0.16 + jw0.32E^{-3}) ohms
Phase	Z3 = (0.24 + jw0.47E^{-3}) ohms

For loads between 1.4 and 4 kVA per phase:

Phase to neutral	$Z1 = (0.20 + jw0.31E^{-3})$ ohms
Neutral	$Z2 = (0.08 + jw0.12E^{-3})$ ohms
Phase	$Z3 = (0.12 + jw0.19E^{-3})$ ohms

For loads greater than 4 kVA per phase:

Phase to neutral	$Z1 = (0.10 + jw0.16E^{-3})$ ohms
Neutral	$Z2 = (0.04 + jw0.06E^{-3})$ ohms
Phase	$Z3 = (0.06 + jw0.10E^{-3})$ ohms

CAUTION

These impedances are not to be used for calculating short circuit current, inrush currents, voltage regulation, or for any purpose except calculating voltage distortion factors.

2.18 NEUTRAL CONDUCTOR

The neutral conductor of a polyphase circuit or of a single-phase 3-wire circuit is that conductor intended to have a potential such that the potential difference between it and any of the other conductors is approximately equal in magnitude and equally spaced in phase.

2.19 NEUTRAL CURRENT

The neutral current in a polyphase circuit is the rms value of the current in the neutral conductor that results from load unbalance and/or harmonic currents of nonlinear loads.

In a single phase circuit using a line-to-neutral source, the neutral current is the rms value of the current in the load.

NOTE

In 3-phase, 4-wire wye systems that supply phase-to-neutral loads with capacitor input filters, third harmonic components of the load currents may cause the neutral current to exceed by 75% the currents in the phase conductors, even under a balanced load condition.

2.20 PRIMARY AC POWER SOURCE

A primary ac power source, such as for computer systems, is the source external to the computer system from which system operating voltages are derived. Examples are 50 Hz or 60 Hz ac commercial mains power.

Ac sources are described in various ways depending on voltage, frequency, single phase or multiphase, and wiring configuration; for example, wye, delta, open delta, and so forth. In addition, sources may be further classified as referenced to earth (*grounded*) or not referenced to earth (*ungrounded*). Although this section describes the letter codings used in European power systems, similar systems may be found in other regions.

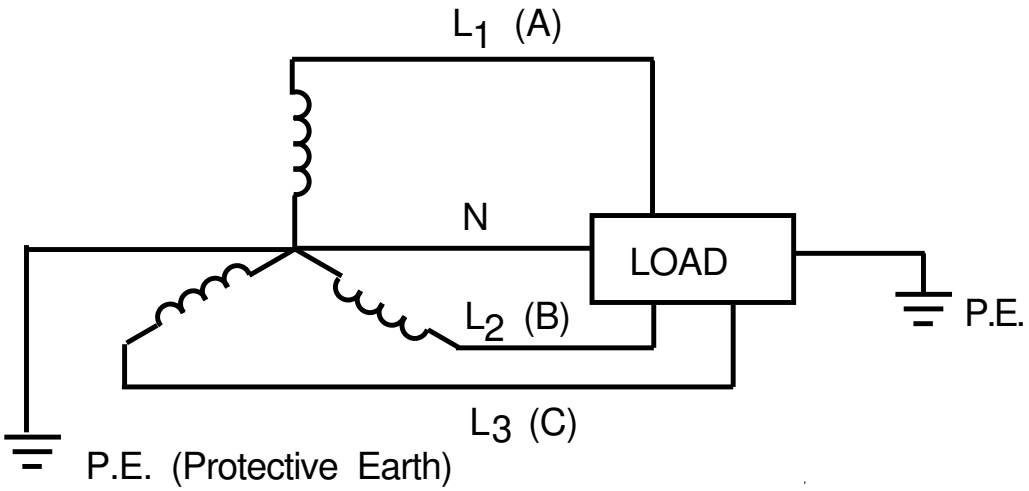
2.20.1 European Power Systems

European power systems are classified according to the methods of grounding (earthing) used and are coded as TT, TN, or IT. The letters are derived from French words as follows:
T (terre)—one point earthed
I (isole)—all live parts isolated from earth, or one point earthed through an impedance
N (neutre)—exposed metal parts connected to the earthed point of the power system

2.20.1.1 TT System

A TT system is a system where the common tie point (neutral) is earthed at the source and where exposed metal parts are earthed. Refer to Figure 2.

Figure 2: TT System



2.20.1.2 IT System

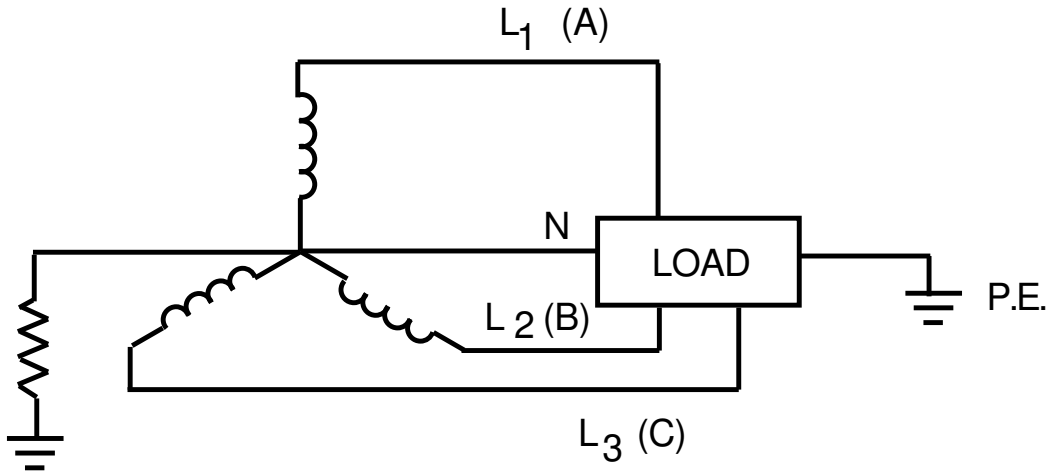
An IT system is a system where the common tie point (neutral) is isolated from earth or connected to earth through an impedance and where exposed metal parts are earthed. Refer to Figure 3.

NOTE

Digital's systems and products are not designed to be connected to IT systems. Where IT systems exist, they must be converted to TT or TN systems to meet Digital product safety requirements.

An IT system is also referred to as an *impedant neutral* system when the neutral is connected to earth through an impedance.

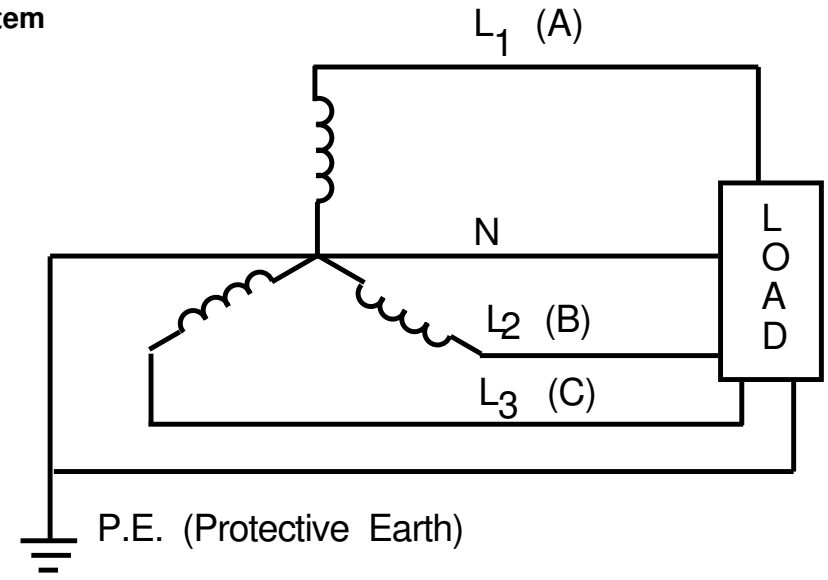
Figure 3: IT System



2.20.1.3 TN System

A TN system is a system where the common tie point (neutral) is earthed at the source and where exposed metal parts are connected to the earth point of the source. Refer to Figure 4.

Figure 4: TN System



2.21 RIDE-THROUGH

Ride-through is the ability of equipment to be impervious to the effects of line voltage sags of various magnitudes and durations.

2.22 RIDE-THROUGH TIME

Ride-through time is the maximum duration of a specified magnitude of a line voltage sag during which the equipment will not initiate its power-down sequence routine.

Because the ride-through time is a function of the magnitude and duration of line voltage sags, it is a variable quantity and may be represented graphically. A ride-through curve may be generated by measurements taking into account worst-case conditions of loading, storage component tolerances, operating frequency, operating temperature, and with the line voltage to the equipment at the nominal-rated value just prior to the voltage sag.

2.23 HOLD-UP

Hold-up is the ability of equipment to provide valid output power for a specified duration of time after a total loss of input power.

2.24 HOLD-UP TIME

The hold-up time is that duration of time measured from the instant of power outage occurring at the point on the input ac voltage waveform where the stored energy in the storage element is at its lowest value to the time when the output voltage has decayed to its lower specified regulation limit.

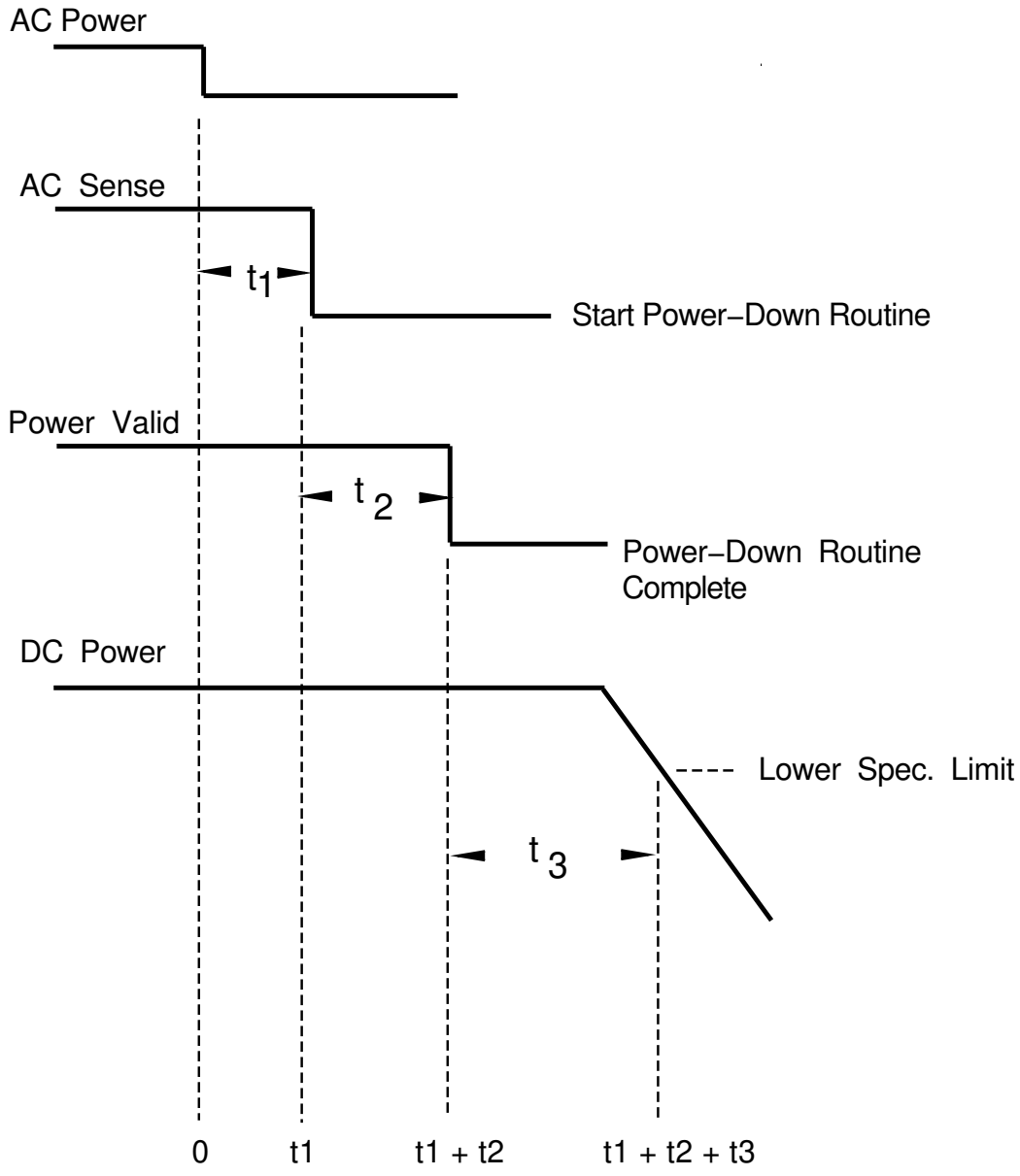
NOTE

It is to be specified at worst-case conditions of load, storage component tolerances, operating frequency, operating temperature, and with the line voltage to the equipment at the specified value, just prior to the total loss (outage), at the minimum steady state value.

2.25 RIDE-THROUGH TIME/HOLD-UP TIME RELATIONSHIP

Figure 5 provides representative waveforms that show the relationship of ac power loss, dc power, and dc signals to initiate power-down routine and completion of power-down routine.

Figure 5: Ride-Through Time/Hold-Up Time Relationship



In Figure 5:

t1 is ride-through time. It represents the time required to sense ac power loss and to provide an output signal to initiate power down routine.

This ride-through time may be any number greater than 0. The shorter this time is made however, the greater the frequency of nuisance shutdowns will occur due to short power line disturbances and noise. This time should be made as long as possible consistent with other product and system requirements and trade-offs of size and cost.

t2 represents the duration required to guarantee orderly power-down of computer operation. This duration is determined by product and system requirements. A typical value might be 5 ms to store all volatile registers away in nonvolatile memory.

t3 represents the duration of valid power remaining following the completion of t2. This time may be any duration equal to or greater than 0.

t1 + t2 + t3 = hold-up time

New power supply designs that must interface with existing power fail detect circuitry must provide sufficient hold-up capacity to be consistent with the specific power fail detect circuit specifications.

NOTE

Typically 20 ms hold-up time duration is required.

New power supply designs incorporating their own power fail detect circuitry must provide sufficient hold-up capacity to be compatible with the detect circuitry and with the appropriate system specification in which they will be used.

2.26 PHASE ROTATION

The order in which the voltages or currents successively reach their positive maximum values in a polyphase circuit. For example: if Phase A, Phase B, Phase C form a positive sequence, the phase rotation is designated as ABC.

3 GENERAL INFORMATION

Public utilities and/or regulatory agencies of any given country usually specify tolerances on various characteristics of utility-generated power. These include voltage, frequency, harmonics, phase angle, and voltage imbalance. Keep in mind that the tolerances specified by utilities and/or regulatory bodies do not include transient behavior due to disturbances caused by various means such as lightning, power-network switching, operation of customer equipment, power factor corrections, and power line faults. The limits as set forth in this standard are based on results and information extracted from studies, reports, standards, Computer Business Equipment Manufacturers Association (CBEMA) findings, and other sources; they constitute a realistic description of the primary ac power that is normally expected to be encountered.

In arriving at these limits, recognition of the factors involved in the designing and manufacturing of equipment to differing power input specifications that are more severe than normally encountered and where these severity conditions are considered as normal or long term was considered. This standard does not include these severe power conditions.

Also, design requirements specified herein are based primarily on the quality of power normally provided by utilities and may not reflect power sources that are not utility provided, such as emergency or standby types or those found in facilities or building complexes with their own generating equipment.

Table 8 lists the ac voltage levels and tolerances used in various parts of the world. The ac distribution configuration used in each major market area is identified by a letter code that corresponds to a specific configuration shown in 5.1.

4 DESIGN REQUIREMENTS

This section establishes design requirements for all power supplies, power controllers, and associated power products that operate from primary ac sources and that are intended for use in Digital computer products and peripheral devices.

This section is primarily written for designers of power products. It is also intended as a guideline and reference for Digital Services, Manufacturing, Test Engineering, Component Engineering, Systems Evaluation Engineering, Environmental Engineering, Product Safety, and Product Assurance.

4.1 VOLTAGE AND FREQUENCY NOMINALS

The voltages and frequencies shown in Table 1 are the most common. All power supply products and computer equipment must be capable of operating from at least one nominal voltage in each major market area listed in Table 1.

To achieve this requirement, it is permissible to incorporate all of the ranges into one product or to make variations of the product.

Table 1: Common Voltages and Frequencies in Major Market Areas

Nominal Voltage V rms		Nominal Frequency Hz	Major Market Area (Note 1)
101	1 Phase	50 and 60	Japan
202	3 Phase (Delta)		
101/202	1 Phase		
120	1 Phase	60	U.S. and Canada
120/240	1 Phase		
208	3 Phase (Wye) (Note 2)		
220	1 Phase	50	Mainland Europe
380	3 Phase (Wye)		
230	1 Phase	50	Israel and New Zealand
400	3 Phase (Wye)		
240	1 Phase	50	UK and Australia
415	3 Phase (Wye)		

NOTES TO TABLE 1

1. **For additional geographical locations, refer to Table 8.**
2. **In some localities, only 2 Phases will be available.**

4.2 RECOMMENDED SYSTEM OPERATING VOLTAGE AND FREQUENCY RANGE

For each of the nominals stated in subhead 4.1, Table 2 defines the voltage and frequency range over which computer systems must operate and meet all functional requirements specified in the computer equipment or systems specifications.

Table 2: Recommended System Operating Voltage and Frequency Range

Nominal Voltage V rms	Nominal Frequency Hz	Voltage Range V rms (See Notes 1 and 2)	Frequency Range Hz
101	50 and 60	90–110	49–51 59–61
120	60	104–128	59–61
202	50 and 60	180–220	49–51 59–61
208	60	180–220	59–61
220	50	190–235	49–51
230	50	200–244	49–51
240	50 and 60	208–256	49–51 59–61
380	50	331–407	49–51
400	50	346–422	49–51
415	50	360–443	49–51

NOTES TO TABLE 2

1. **These ranges are steady state values as measured at the common tie point of the computer equipment's power system, that is, wall receptacle or breaker panel, and include allowances for normal distribution voltage drops within the customer's wiring system.**

   These are the ranges to be recommended to the customer to provide reliable operation of equipment and systems, and must appear in the equipment's or system's specifications available to the customer.

2. **These ranges do not include any allowances for short-term power line disturbances, such as sags or surges, or long-term brownouts, nor do they include allowances for normal distribution voltage drops within the computer's ac wiring system.**

4.2.1 System Start-up Voltage

Computer products, peripheral devices, terminals, and systems must be capable of a normal start-up, become fully operational, and meet equipment/system specifications from a power source whose line voltage is at the steady state low-line value specified.

4.2.2 Power Quality

To ensure trouble-free system operation from power problems, it is recommended that Digital Services environmentalists ascertain the quality of power provided by the customer prior to installation of the equipment. The characteristics of the power source should fall within the specified limits.

a. Minimum and maximum steady state voltage and frequency limits of subhead 4.1.1 should not be exceeded.

b. Phase rotation should be ABC (refer to subhead 4.13).

c. Voltage harmonic distortion should be less than 5% with any single harmonic not exceeding 3%.

d. Voltage waveform crest factor should be greater than 1.4.

e. Phase angle unbalance should not exceed limits specified in subhead 4.4.

f. Voltage unbalance should not exceed limits specified in subhead 4.5.

4.2.3 Design and Test Ranges for Power Products Using AC Power

Power supplies, power controllers, and associated power devices shall be designed and tested to limits specified in Table 3.

Table 3: Voltage and Frequency Design Ranges

Nominal Voltage V rms	Voltage Design Range (Notes 1, 2, and 3) V rms	Frequency Design Range (Note 4) Hz
101	88 - 110	47 - 53 and 57 - 63
120	93 - 132	57 - 63
202	176 - 220	47 - 53 and 57 - 63
208	161 - 229	57 - 63
220	176 - 242	47 - 53
230	181 - 253	47 - 53
240	186 - 264	47 - 53 and 57 - 63
380	305 - 418	47 - 53
400	313 - 438	47 - 53
415	329 - 457	47 - 53

NOTES TO TABLE 3

1. **These ranges are steady state values as measured at the common tie point of the equipment's power system, that is, wall receptacle or circuit breaker panel, and include allowances for brownout and some voltage sag conditions.**

   Because these are design ranges, they must not appear in the product or system specifications or documentation that is available to customers. These design ranges must appear in the engineering product specification sheets.

2. **Where power supplies are designed for cabinet-mounted equipment (such as the BA11-K), and where that equipment receives power through an ac power controller, the power supply design engineers must be cognizant of additional voltage drops that will result in the cabinets' ac distribution. For design purposes, reduce the low-line value in Table 3 by 2 V to allow for the voltage drop across the power cord and power controller.**

3. **Power down routines, if required, shall be initiated at or below the minimum design voltage specified in Table 3, and the product shall be required to meet performance requirements until the power down routine is complete.**

4. **Equipment that is not frequency sensitive needs to be tested only at the equipment's rated nominal frequency or frequencies.**

4.3 VOLTAGE VARIATION: DYNAMIC

Equipment shall be designed to operate without interruption for a ramp change of ±10% of nominal voltage for 0.1 second maximum duration with a maximum rate of change of voltage not to exceed 1 volt per microsecond and occurring not more frequently than once every 10 seconds.

4.4 FREQUENCY VARIATIONS: STEADY STATE

Equipment shall be designed to operate from 47 to 53 Hz when connected to a 50 Hz source and from 57 to 63 Hz when connected to a 60 Hz source.

NOTE

In many building complexes, large business facilities, and hospitals, it is becoming more common for customers to provide their own power-generating equipment. In these cases, frequency regulation of ± 3 Hz is typical.

4.5 PHASE ANGLE UNBALANCE

Equipment requiring 3-phase power shall operate satisfactorily when a maximum phase variation of 5 degrees from the nominal 120-degree relation is encountered.

NOTE

This requirement only applies to equipment such as 3-phase motors, blowers, and products using 3-phase rectifier circuitry. This requirement is not necessary for 3-phase equipment composed entirely of single-phase loads.

4.6 VOLTAGE UNBALANCE

Equipment requiring 3-phase power shall operate satisfactorily when the voltage unbalance is 5% or less.

NOTE

This requirement only applies to equipment such as 3-phase motors, blowers, and products using 3-phase rectifier circuitry. This requirement does not apply to 3-phase equipment comprised entirely of single-phase loads.

4.7 UNDERVOLTAGES AND OUTAGES

All components, power supplies, and power systems shall be capable of withstanding undervoltage conditions and power interruptions, on one or more phases of any duration, without physical damage.

4.8 OVERVOLTAGE

Equipment shall be designed to accept an overvoltage of 1.25 times its highest rated nominal voltage for a period of 1 second, without causing system performance degradation or equipment damage.

4.9 INRUSH CURRENT

Equipment designers must be aware of the initial and restart currents under worst case of line voltage (usually high), load (could be at no load or full load), and temperature (usually low) and use suitably rated components to withstand the inrush currents without damaging front-end components, blowing equipment fuses, or tripping equipment circuit breakers.

For equipment having more than one inrush current peak, such as with step-start circuits, the multiplying factors in subhead 4.9.1 apply to the highest peak that results. This highest peak may be the initial (first) peak or any of succeeding inrush peaks.

Equipment electrical specification and product maintenance manuals must specify the peak magnitude and duration of the worse case initial and restart inrush currents.

4.9.1 Inrush Current Limits

The peak of the inrush current shall be limited in accordance with the following requirements.

A. For single-phase, line-to-neutral connected equipment

Rated Current of Equipment (at nominal voltage)	Max. 1/2-Cycle Peak Inrush Current (at nominal voltage)
$\leq$ 3 A rms	45 A
> 3 A rms; < 24 A rms	15 times rated
$\geq$ 24 A rms	12 times rated

B. For single-phase, line-to-line or multiphase connected equipment

Rated Current of Equipment (at nominal voltage)	Max. 1/2-Cycle Peak Inrush Current (at nominal voltage)
$\leq$ 16 A rms	Larger of 45 A or 20 times rated
> 16 A rms; < 24 A rms	15 times rated
$\geq$ 24 A rms	12 times rated

The following notes apply to this requirement:

NOTE 1

The *rated current* of a device or equipment is the current that is marked on the equipment nameplate.

NOTE 2

For test purposes, the inrush current is to be measured as specified in DEC STD 122-1. The inrush current shall not be greater than the product of the specified *rated current* of the device and the appropriate multiplying factor given above.

NOTE 3

For equipment containing power supplies and power controllers that are designed for a higher power application than the rating of the equipment in which they are installed, the inrush current may exceed that which is allowed by this standard. In these cases, a waiver must be requested.

4.9.2 Restart Inrush Current

At this time, no limits are specified for restart inrush current. However, the equipment designer must be aware of the restart inrush current and use suitably rated components to withstand the maximum restart current without damaging the equipment, blowing equipment fuses, tripping equipment circuit breakers, or welding switches and/or contacts. In addition, it is a requirement that the restart inrush current be measured under the worst condition and that it be specified in the electrical specification and the product maintenance manual.

4.10 HIGH VOLTAGE TRANSIENTS

High voltage transients on ac power distributions are basically caused by two types of events:

a. Load or system switching

b. Lightning

Switching includes any of the following:

a. Turning equipment on or off

b. Operation of circuit breakers and fuse blowings under fault conditions

c. Switching of power factor correction capacitors

d. Switching of loads by the power utility or customer

Lightning effects include:

a. Nearby strikes setting up electromagnetic fields that induce high voltages

b. Direct strikes on primary feeders injecting high currents and producing high voltages

c. Coupling of rapid collapse (dV/dt) of voltage caused by lightning arrestor operation

d. High current coupled into ground circuits

This standard deals with surge voltages and currents likely to be experienced on power systems primarily located within buildings, which includes long branch circuits and outlets as opposed to major feeder lines, service drops from pole to buildings, and overhead lines.

The rate of occurrences varies over wide limits depending on geographical location and power system load operating characteristics. Voltage amplitudes and the interaction of the surge energy also depends on relative impedance levels of the ac system, suppression networks, and load impedances. Therefore, a prediction of amplitudes, waveforms, and energy is difficult.

To ensure that equipment is capable of withstanding high voltage transients, all new designs shall meet the following requirements.

4.10.1 Equipment Transient Voltage Requirements

Design and test requirements specified in this standard are based on power line transients as described in ANSI/IEEE C62.41-1991, *IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits*. Design limits specified in this standard may differ from the values given in ANSI/IEEE C62.41-1991.

For design and test purposes, this standard mandates that Digital products will meet either Level A, Level B, or Level C requirements. The selection of Level A, Level B, or Level C requirements is based on the rated input current of the product or device at the nominal line voltage. The selection criteria for each level are:

Level A (Must meet all three criteria)

- Single-phase products and devices that have a rated input current of 12.0 amperes or less
- Uses a single-phase ac power plug with a current rating less than 22.0 amperes
- Is connected between line and neutral

Level C

- Single-phase or three-phase products and devices that have a rated input current of 33.0 amperes or more per phase

Level B

- All other single-phase or three-phase products and devices not meeting the selection criteria of Level A or Level C

The selection of Level A, Level B, or Level C requirements is independent of the nominal voltage for the nominal voltages listed in this standard.

NOTE

In some cases, a 100 V to 120 V product or device that must be designed and tested to Level B requirements may meet the Level A selection criteria when the product or device is in the 220 V to 240 V configuration. In these cases, the product in the 220 V to 240 V configuration may be evaluated either to Level A or Level B requirements at the option of the product manager.

NOTE

In some cases, a 100 V to 120 V (line-to-neutral) or 200 V to 240 V (line-to-line) product or device that must be designed to Level C requirements may meet the Level B selection criteria when the product or device is in its 220 V to 240 V (line-to-neutral) or 380 V to 415 V (line-to-line) configuration. In these cases, the product or device in the 220 V to 240 V or 380 V to 415 V configuration may be evaluated either to Level B or Level C requirements at the option of the product manager.

NOTE

For products that must meet only Level A requirements, but may be used in a harsher power line environment, such as in industrial and manufacturing environments, the product manager shall consider meeting the harsher Level B requirements.

These are engineering product qualification tests, not manufacturing or in field tests. Individual units subjected to these tests are not to be shipped to customers.

Since tests are to be conducted on products at both the low voltage range (100 V to 120 V) and high voltage ranges (200 V to 240 V), the same unit shall not be used for both test runs. This is regardless of whether the product can be reconfigured electronically or by other means, such as with voltage select switch, tap changes, jumpers, and so on. For example, a system that can be reconfigured from 120 V to 240 V by simply replacing a power controller device, shall not be used during the qualification run for both the low and high voltage range tests.

Old products are not required to be upgraded to the requirements of this subhead. New products or configurations using old subassemblies are required to meet this standard, unless a waiver is obtained. In such cases, upgrading old subassemblies is a product management decision.

For the purposes of this standard, a product is defined as a device with a single ac power connection with all attached ac load devices.

4.10.1.1 Equipment Survival Limits

The product must not experience any permanent damage, and must return to an operable state (with or without operator-level intervention including restoring over-current devices) after the application of Level A, Level B, or Level C survival transient test voltages, as applicable for that device.

The transient overvoltages are applied according to 4.10.2.

Table 4: Equipment Survival Limits

Test Requirement Level	A	———B———		———C———	
Figure	6a	6a	6b and 6c	6a	6b and 6c
Waveform type	Ring	Ring	Impulse	Ring	Impulse
Vpk (open circuit)	4 kV	4 kV	4 kV	6 kV	6 kV
Effective surge Z (ohms)	30	12	2	12	2

NOTE

Both ring wave and impulse waveforms are required for Level B and Level C testing.

4.10.1.2 Equipment Performance Susceptibility Limits

The system shall perform to specification during and after the application of the Level A, Level B, or Level C susceptibility transient test voltages as applicable for that device without the irretrievable loss of data or processing operations or requiring operator intervention.

The transient overvoltages are applied according to 4.10.3.

Table 5: Equipment Performance Susceptibility Limits

Test Requirement Level	A	———B & C———	
Figure	6a	6a	6b and 6c
Waveform type	Ring	Ring	Impulse
Vpk (open circuit)	2 kV	3 kV	3 kV
Effective surge Z (ohms)	30	12	2

NOTE

Both ring wave and impulse waveforms are required for Level B and Level C testing.

If the product invokes automatic correction or recovery operations to meet this requirement, these operations must not be used or required with the application of the transient voltages below 1000 V and the correspondingly reduced current.

4.10.1.3 Ring Wave and Impulse Waveforms

This subhead includes figures showing ring wave and impulse waveforms.

Figure 6a: 0.5 μs/100 kHz Ring Wave—Open Circuit Voltage or Short Circuit Current

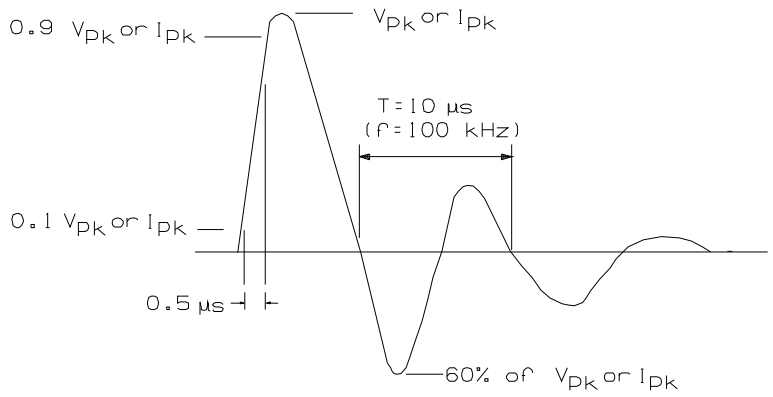


Figure 6b: 1.2 x 50 Voltage Impulse—Open Circuit

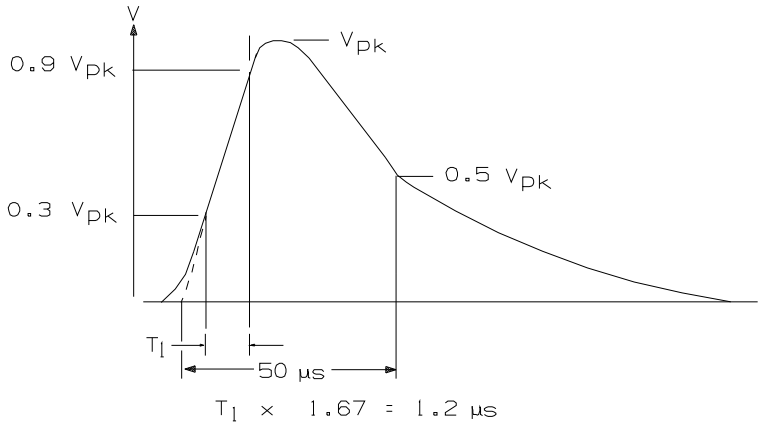
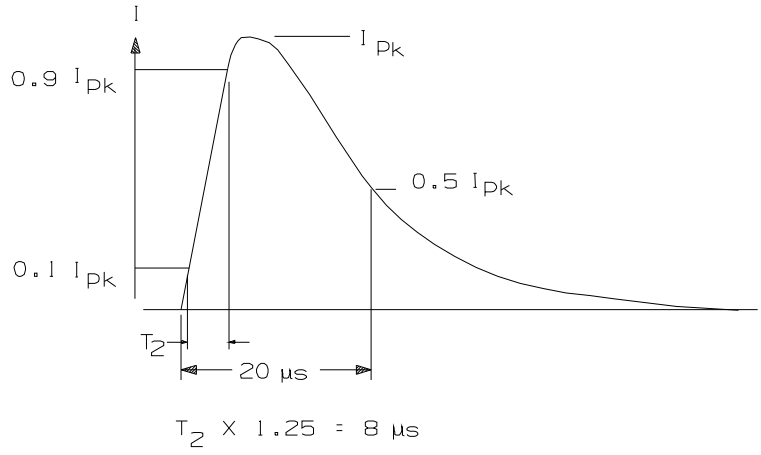


Figure 6c: 8 x 20 Current Impulse—Short Circuit



4.10.2 Application of Survival Limit Waveforms

During the test, operation of the product shall simulate the actual customer configuration including parallel and serial communication links that are connected to other computer equipment.

With the equipment in the operational state, the transients are applied both in the normal mode (line-to-neutral or line-to-line) and common mode (line-to-ground and neutral-to-ground), and in both polarities at the zero crossing, positive and negative peaks of the ac sinusoid voltage waveform.

With the equipment in the normal *Off* state, transients are applied both in the normal mode (line-to-neutral or line-to-line) and common mode (line-to-ground and neutral-to-ground), and in both polarities at the positive peak of the ac sinusoid voltage waveform.

The transients are applied at the ac power plug, with the equipment's power cord installed. Field wired equipment may use a flexible cord with a maximum length of 4.6 m (15 ft).

The time-averaged power of the transients is to be limited to 0.5 W.

As an aid to the understanding of the test conditions described above, the following subheads gives the breakdown of the different test conditions. An explanation on the use of terms of the following subhead is given as follows:

On/Off	*On* signifies that the equipment under test is in the normal operational state. *Off* signifies that the equipment under test is connected to the ac power source but is in the Off state.
Polarity	The + indicates that the transient is applied to provide a positive initial voltage/current peak. The - indicates that the transient is applied to provide a negative initial voltage/current peak.
Normal Mode	The transient is applied between line to neutral or line to line depending on the equipment's ac input connection method.
L-N	Transient is applied line to neutral.
L-L	Transient is applied line to line. The numbers indicate the phase for multiphase equipment.
Common Mode	The transient is applied between the load-carrying conductors (line(s) and neutral) and the ground conductor. For common mode test for class II (no ground conductor) devices, common mode transients are applied between power lines and the ground reference plane, which is placed under the device during these tests.
L-G	Transient is applied line to ground.
N-G	Transient is applied neutral to ground. L-G and N-G transients can be applied simultaneously.

The number *3* indicates the total number of transients applied to the equipment in the *On* state. One of the transients is to be applied at the zero crossing of the voltage ac waveform; a second transient is to be applied at the positive peak (90 degrees) of the ac voltage waveform; and a third transient is to be applied at the negative peak (270 degrees) of the ac voltage waveform.

The number *1* indicates the total number of transients applied to the equipment in the *Off* state. This transient is to be applied at the positive peak (90 degrees) of the ac voltage waveform.

4.10.2.1 Level A Survival Testing—Single-Phase Devices

Level A Survival Test Requirements
Single–Phase Devices

On/Off	Polarity	Normal Mode	Common Mode	
		L–N	L–G	N–G
On	+	3	3	3
On	–	3	3	3
Off	+	1	1	1
Off	–	1	1	1

4.10.2.2 Level B and Level C Survival Testing—Single-Phase Devices

Level B and Level C Survival Test Requirements Single–Phase Devices							
On/Off	Polarity	Normal Mode		Common Mode			
		(L–N or L1–L2)		L1–G		N–G(or L2–G)	
		Ring	Impulse	Ring	Impulse	Ring	Impulse
On	+	3	3	3	3	3	3
On	–	3	3	3	3	3	3
Off	+	1	1	1	1	1	1
Off	–	1	1	1	1	1	1

4.10.2.3 Level B and Level C Survival Testing—Three-Phase Devices

Three-phase products/devices configured totally with line-to-neutral (no line-to-line) loads need only to be subjected to line-to-neutral applied transients and only on phases which have loads connected across them.

Three-phase products/devices configured totally with line-to-line (no line-to-neutral) loads need only to be subjected to line-to-line applied transients and only on lines which have loads connected across them.

Three-phase products/devices configured with both line-to-neutral and line-to-line loads shall be subjected to both line-to-neutral and line-to-line applied transients, and only across those phases and lines as are appropriate.

Level B and Level C Survival Test Requirements Three–Phase Devices with Line–to–Neutral Loads															
On–Off	Polarity	Normal Mode (L–N)						Common Mode (L–G/N–G)							
		Ring			Impulse			Ring				Impulse			
		L1–N	L2–N	L3–N	L1–N	L2–N	L3–N	L1–G	L2–G	L3–G	N–G	L1–G	L2–G	L3–G	N–G
On	+	3	3	3	3	3	3	3	3	3	3	3	3	3	3
On	–	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Off	+	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Off	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Level B and Level C Survival Test Requirements Three–Phase Devices With Line–to–Line Loads											
On–Off	Polarity	Normal Mode (L–L)						Common Mode (L–G)			
		Ring			Impulse			Ring			Impulse		
		L1–L2	L2–L3	L3–L1	L1–L2	L2–L3	L3–L1	L1–G	L2–G	L3–G	L1–G	L2–G	L3–G
On	+	3	3	3	3	3	3	3	3	3	3	3	3
On	–	3	3	3	3	3	3	3	3	3	3	3	3
Off	+	1	1	1	1	1	1	1	1	1	1	1	1
Off	–	1	1	1	1	1	1	1	1	1	1	1	1

4.10.3 Application of Performance Susceptibility Waveforms

During the test, operation of the product shall simulate actual customer configuration including parallel and serial communication links that are connected to other computer equipment.

With the equipment in operational state, the transients are randomly (nonfixed phase relationship to the ac voltage waveform) applied both in the normal mode (line-to-neutral or line-to-line) and common mode (line-to-ground *and* neutral-to-ground), and applied in both polarities.

The transients are applied at the ac power plug, with the equipment's power cord installed. Field wired equipment may use a flexible cord with a maximum length of 4.6 m (15 feet).

The time-averaged power of the transients is to be limited to 0.5 W.

4.10.3.1 Level A Performance Susceptibility Testing—Single-Phase Devices

The following table shows the breakdown of the test conditions described in subhead 4.10.3 and the minimum number of transients to be applied to the device under test.

Level A Performance Test Requirements
Single–Phase Devices

On/Off	Polarity	Normal Mode	Common Mode	
		L–N Ring	L–G Ring	N–G Ring
On	+	10	10	10
On	–	10	10	10
Off*	+	10	10	10
Off*	–	10	10	10

NOTE

*** Only required if product has line powered devices connected before normal power on/off means. (Battery backup unit (BBU), clocks, stand-by circuits)**

4.10.3.2 Level B and Level C Performance Susceptibility Testing—Single-Phase Devices

Level B or Level C Performance Test Requirements Single–Phase Devices							
On/Off	Polarity	Normal Mode		Common Mode			
		(L–N or L1–L2)		L1–G		N–G(or L2–G)	
		Ring	Impulse	Ring	Impulse	Ring	Impulse
On	+	10	10	10	10	10	10
On	–	10	10	10	10	10	10
Off*	+	10	10	10	10	10	10
Off*	–	10	10	10	10	10	10

NOTE

*** Only required if product has line powered devices connected before normal power on/off means. (Battery backup unit (BBU), clocks, stand-by circuits)**

4.10.3.3 Level B and Level C Performance Susceptibility Testing—Three-Phase Devices

Three-phase products/devices configured totally with line-to-neutral (no line-to-line) loads need only to be subjected to line-to-neutral applied transients and only on phases that have loads connected across them.

Three-phase products/devices configured totally with line-to-line (no line-to-neutral) loads need only to be subjected to line-to-line applied transients, and only on lines that have loads connected across them.

Three-phase products/devices configured with both line-to-neutral and line-to-line loads shall be subjected to both line-to-neutral and line-to-line applied transients, and only across those phases and lines as are appropriate.

Level B and Level C Performance Test Requirements Three–Phase Devices With Line–to–Neutral Loads																
On/ Off	Polar– ity	Normal Mode (L–N)						Common Mode (L–G/N–G)								
		Ring			Impulse			Ring				Impulse				
		L1–N	L2–N	L3–N	L1–N	L2–N	L3–N	L1–G	L2–G	L3–G	N–G	L1–G	L2–G	L3–G	N–G	
On	+	10	10	10	10	10	10	10	10	10	10	10	10	10	10	
On	–	10	10	10	10	10	10	10	10	10	10	10	10	10	10	
Off*	+	10	10	10	10	10	10	10	10	10	10	10	10	10	10	
Off*	–	10	10	10	10	10	10	10	10	10	10	10	10	10	10	

NOTE

*** Only required if product has line powered devices connected before normal power on/off means. (Battery backup unit (BBU), clocks, stand-by circuits)**

Level B and Level C Performance Test Requirements Three–Phase Devices Line–to–Line Loads														
On–Off	Polarity	Normal Mode (L–L)						Common Mode (L–G)						
		Ring			Impulse			Ring			Impulse			
		L1–L2	L2–L3	L3–L1	L1–L2	L2–L3	L3–L1	L1–G	L2–G	L3–G	L1–G	L2–G	L3–G	
On	+	10	10	10	10	10	10	10	10	10	10	10	10	
On	–	10	10	10	10	10	10	10	10	10	10	10	10	
Off*	+	10	10	10	10	10	10	10	10	10	10	10	10	
Off*	–	10	10	10	10	10	10	10	10	10	10	10	10	

NOTE

*** Only required if product has line powered devices connected before normal power on/off means. (Battery backup unit (BBU), clocks, stand-by circuits)**

4.11 EQUIPMENT-GENERATED VOLTAGE TRANSIENTS

All new equipment shall be designed so it does not cause voltage transients greater than 1.0 kV to appear on its input terminals when turning the equipment on or off or while the equipment is operating.

4.12 EQUIPMENT SAFETY

All equipment designed in accordance to requirements in this standard shall meet the requirements of *DEC STD 119-1 Digital Product Safety—Design Criteria* or *DEC STD 080-1 Digital Product Safety Industrial Control Equipment—Design Criteria*, or both according to the intended market.

4.13 HOLD-UP TIME

All power supplies that must operate with power fail routines shall be designed with sufficient hold-up capacity to provide valid power, within specified limits, for the duration necessary to achieve an orderly computer shutdown, meaning no loss of data.

This requirement shall be met at worst-case conditions of load, energy storage component tolerances, operating frequency, operating temperature, and line voltage.

4.14 PHASE ROTATION SENSITIVE LOADS

Equipment sensitive to phase rotation sequence that may become damaged or that may cause damage to other portions of the system shall have suitable means to detect phase sequence to prevent damage. An example is 3-phase motors. Phase rotation of building wiring shall not be relied on as being and remaining correct.

4.15 VOLTAGE CREST FACTOR

The crest factor of a sinusoidal voltage or current waveform is equal to 1.414. In typical power conversion equipment, line currents are nonsinusoidal and are characterized by current crest factors of 2.5 to 3.0. These currents flow for only a portion of each half cycle and near the peak of the voltage waveform that may cause flattening of the voltage waveform and results in a voltage crest factor of less than 1.414. In power supplies, the effect is that the storage capacitors are charged to a lower voltage and contain less energy, which in turn affects the ride-through and hold-up times.

Although no survey has been made either by Digital or the utility industry, flat topping of the line voltage has been a common occurrence and observed both by power supply engineers and Digital Services engineers.

For design purposes, the value that shall be used for the voltage crest factor when determining the input capacitor values is 1.37.

For determining the working voltage of components, a sinusoidal waveform shall be assumed with 1.414 crest factor.

4.16 DIRECT CURRENT LIMITATIONS IN AC INPUT POWER CIRCUITS

Input ac power circuits can contain direct current components due to asymmetric loading with respect to voltage polarity. These direct currents can affect the ac distribution system including improper operation of current sensing devices, overheating of magnetic elements, distorted source voltages, and corrosion in the presence of electrolyte.

4.16.1 Requirements

These requirements apply at the ac power input line cord of a power supply. Accumulation of direct current is permissible in a source line cord of a product in which multiple power supply line cords are connected to that common source line cord.

To reduce the extent of these effects, the use of circuits that would cause direct current in the ac power lines shall not be used except as intentional direct current on an ac input line limited to sensing and control, and bias or start-up circuits only. The total continuous calculated sensing and control direct current power presented to the ac line is to be limited to either of the following.

Circuit Configuration	Circuit Power Limit
Line to neutral	The lesser of 10% of rated ac input power or 10 W
OR	
Line to line	The lesser of 10% of rated ac input power, or 20 W

It is not permitted to have intentional direct current in L-G or N-G configurations.

NOTE

The direct current attributed solely to the effect of component tolerance mismatch on a symmetrically configured load is presumed to be in compliance with this requirement, provided that parts used are of normal commercial tolerance.

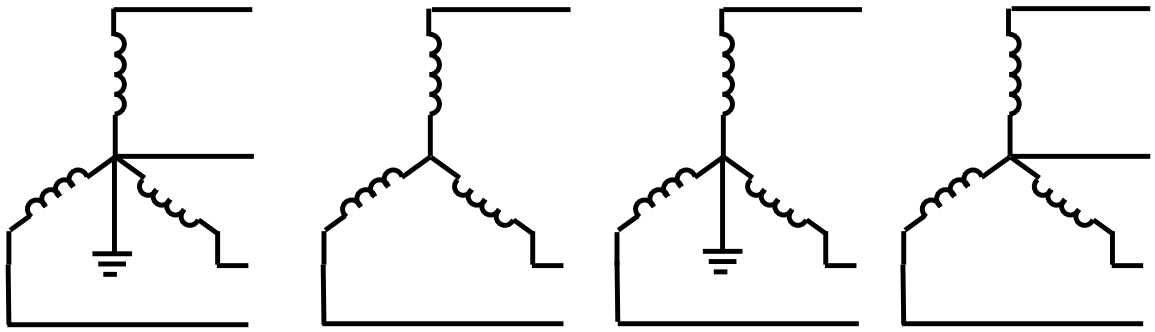
5 DESIGN GUIDELINES

The following subheads define the design guidelines.

5.1 AC DISTRIBUTION

The main ac distribution configurations usually encountered are shown in the following subheads. Each configuration is identified by a letter code that is used with Table 8.

5.1.1 Three-Phase Star (Wye)



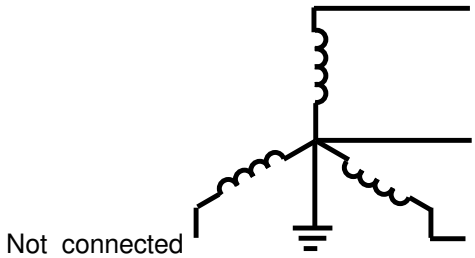
A. 4–Wire, Neutral Earthed

B. 3–Wire

C. 3–Wire, Neutral Point Earthed

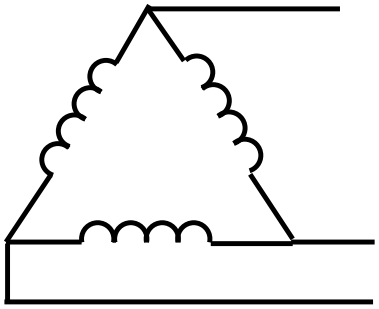
D. 4–Wire, Non–Earthed Neutral

5.1.2 Two-Phase Star (Wye)

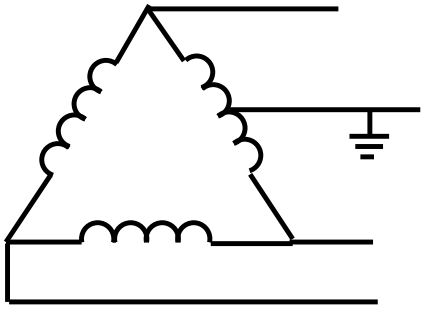


E. 3–Wire, Neutral Earthed

5.1.3 Three-Phase Delta

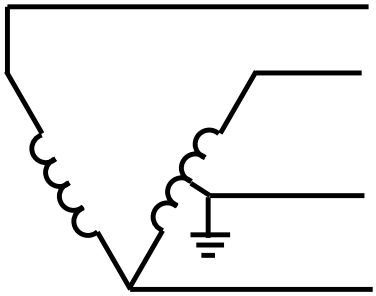


F. 3–Wire

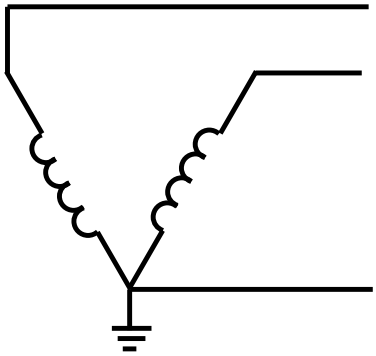


G. 4–Wire, Phase Midpoint Earthed

5.1.4 Three-Phase Open Delta

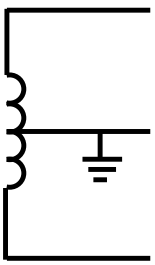


H. 4–Wire, Phase Midpoint Earthed

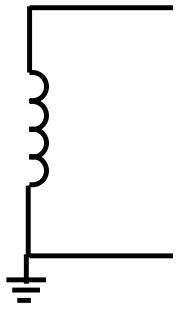


J. 3–Wire, Phase Junction Earthed

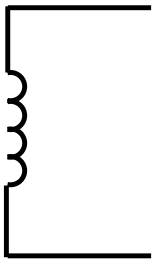
5.1.5 Single-Phase



K. 3–Wire, Earthed Midpoint



L. 2–Wire, Phase End Earthed



M. 2–Wire, Nonearthed

5.2 SINGLE-PHASE LOADS

Three-phase, 3-wire, Wye distribution systems may be solidly grounded or ungrounded, but are not intended to supply loads connected phase to neutral (as are the 4-wire systems).

Single-phase loads may be supplied from single-phase systems or from 3-phase systems. Loads are connected phase to phase when supplied from 3-phase, 3-wire systems, and either phase to phase or phase to neutral from 3-phase, 4-wire systems.

When single-phase loads are distributed over the three phases for load balance, it is better to use a Wye (Y) connection to permit optional single-phase operation when the customer requires it. However, when the input line current for the single-phase load necessitates high current rated circuit breakers, it is better to connect the loads in a delta (Δ) configuration and to use phase-to-phase voltages to reduce the single-phase equipment's circuit breaker rating and size.

5.3 BLOWERS AND FANS

Because the amount of air impelled by blowers and fans varies with the voltage, frequency, and altitude, the equipment shall be adequately cooled under the worst combination of voltage, frequency, and altitude.

5.4 CIRCUIT BREAKERS

Because the line current of equipment at 240 V is approximately half that which is required at 120 V, circuit breakers and other protective devices may need to be changed. Therefore, circuit breakers and other protective devices should be easily accessible or mounted in replaceable subassemblies.

5.5 POWER CORDS AND CORD SETS

Refer to *DEC STD 002-0 AC Power Wiring, Safety Earth Grounding, Plugs and Receptacle Information and Requirements* for the selection of wire sizes and color-coding information.

5.6 AC WIRING

Ac wiring should be separated from dc cables to allow ac wiring to be replaced and to minimize RFI coupling. Refer to *DEC STD 186-0 Signal Integrity* for further details on ac wiring rules.

5.7 FREQUENCY CHANGES

Wherever possible, the changes necessary for 50 Hz or 60 Hz operation will be independent of those changes necessary to change the input voltage.

5.8 AC MOTORS

Because the speed of ac motors depends on the applied frequency, the designer has as alternatives:

- A design that will operate properly at either 50 Hz or 60 Hz without modification
- Change linkages (gears or pulleys and belts)
- Use dc brushless motors

In those cases where a change of motors is unavoidable, the motor should be easily accessible and removable. For the designer in a 60-Hz area, remember that a 50-Hz motor of identical power rating tends to be 20% larger in volume. The speed of synchronous and induction motor varies in direct proportion to frequency. Computer equipment may malfunction if frequency changes more than ± 2%.

5.9 CONSTANT VOLTAGE TRANSFORMERS

Output voltages of constant voltage transformers (CVTs) and ferro-resonant transformers will change about 1.4% for each 1% change in line frequency.

5.10 VOLTAGE CHANGES

To accommodate the distribution voltages of 101 V and 202 V, or 120 V and 240 V, equipment should be designed for dual ranges with a 2:1 ratio. If it is necessary to make series-to-parallel changes on the input to the equipment, the following methods may be used:

- Internal jumpers with Fast-On terminals (for currents less than 6 amperes) or screw-type solderless connectors
- Quick-change connector inside the equipment
- Quick-change input box that is different for each voltage range
- Internal or an external voltage select switch
- Electronic automatic voltage select circuit.

5.11 PHASE BALANCING

Many units in a computer system require single-phase power. When these systems use 3-phase power, the loads should be distributed for the best possible load balance on the 3-phase source. In 3-phase, 4-wire distributions, load unbalance causes neutral currents to flow, which in turn causes reduced power system efficiency, increased power consumption, increased operating costs, and can generate noises that may be reflected back into the computer system. Keep in mind, however, that balancing of line-to-neutral nonlinear loads will not reduce the third harmonic current component in the neutral conductor.

5.12 LEAKAGE CURRENT

The maximum leakage current of a cabinet or multiple cabinets with a single power cord must not exceed 3.5 mA, except as described in DEC STD 119-1.

In order to achieve the 3.5 mA requirement, the maximum limit for any single option with a power supply and designed for cabinet mounting should not exceed 0.5 mA rms and for any power controller should not exceed 1.5 mA rms.

5.13 INTERPHASE CURRENT UNBALANCE FOR CONFIGURED SYSTEMS

System configurations using 3-phase power should be connected to meet the less restrictive of two limitations: 5 amperes or 20%.

For the definition of current unbalance, refer to subhead 2.9.

5.14 POWER REQUIREMENTS IN GIA

Digital's General International Area (GIA) covers more than 108 countries. The countries presenting the most challenging power requirements are Japan and Western Australia. Utilities in Japan provide 101 V rms and 202 V rms at both 50 Hz and 60 Hz. According to GIA sales, 60% of computer equipment in Japan operates on 50 Hz and 40% operates on 60 Hz. Western Australia utilities provide a nominal voltage of 250 V rms.

5.15 SINGLE-PHASE POWER LIMITATIONS FOR VARIOUS COUNTRIES

Table 6: Single-Phase Power Limitations for Various Countries

Country	Electricity Supplies	Single-Phase Power Limitations
Belgium	380/220 V, 50 Hz, 3-phase, 4-wire with the neutral point earthed	3 kVA but may vary according to local power company
Denmark	380/220 V, 50 Hz, 3-phase, 4-wire with the neutral point earthed	2 kVA for single-phase. Equipment over 2 kVA to be connected to at least two phases. Equipment over 5 kVA to be connected to 3-phase
France	380/220 V, 50 Hz, 3-phase, 4-wire with the neutral point earthed	3 kW to 4 kW according to local requirements
Germany	380/220 V, 50 Hz, 3-phase, 4-wire with the neutral point earthed	3 kVA for plug-connected equipment
Italy	380/220 V, 50 Hz, 3-phase, 4-wire with the neutral point earthed	10, 15, 16, or 25 A dependent upon type of supply circuit provided
Republic of Ireland	380/220 V, 50 Hz, 3-phase, 4-wire with the neutral point earthed	13 or 15 A, dependent upon type of supply circuit provided
Luxembourg	380/220 V, 50 Hz, 3-phase, 4-wire with the neutral point earthed	10 A for plug connected equipment or 16 A if equipment protected by circuit breaker
Netherlands	380/220 V, 50 Hz, 3-phase, 4-wire with the neutral point earthed	3.5 kW for plug connected equipment
United Kingdom	415/240 V, 50 Hz, 3-phase, 4-wire with the neutral point earthed	13 A, dependent upon type of supply circuit provided
U.S. and Canada	208/120 V, 60 Hz, 3-phase, 4-wire with the neutral point earthed	15, 20, or 30 A dependent upon type of supply circuit provided
Japan	202 V, 50 and 60 Hz, 3-phase, 3-wire delta 202/101 V, 50 and 60 Hz, 1-phase, 3-wire	15 A on 101 V circuits. On 202 V, dependent on type of circuit provided

5.16 CONNECTING OF 120-VOLT FANS AND BLOWERS FOR 120 V OR 240 V POWER

In some older Digital products where multiple cooling fans are used, the adaptation from 120 V to 240 V has been accomplished with a parallel or series combination of fans. Connecting two 120 V fans in series across a 240 V (or 220 V) power source does not ensure proper voltage distribution, and failure of one fan may cause complete loss of cooling. This connection must be avoided unless provided with a 240 V center-tapped power source for center tapping the two series fans.

5.17 MASS STORAGE DEVICES

Some mass storage devices using equipment primarily designed to operate from 220 V to 240 V nominals are connected across the 208 V line-to-line voltage for operation in the U.S. and Canada. Most 220 V to 240 V rated equipment such as power controllers and power supplies are designed to low line limit of 180 V, this is 25% down from a 240 V nominal but only 13% down from a 208 V nominal. Therefore, tape drives and disk units using 240 V power controllers and power supplies do not have any significant protection against brownout conditions and are also more susceptible to shut downs due to short voltage dips. This compromises the overall availability of systems. Equipment primarily designed for 220 V to 240 V nominal is not intended for operation from 208 V nominal.

5.18 OPERATION IN JAPAN AND AUSTRALIA (WESTERN)

Equipment designed to operate from a 120 V nominal is not intended for operation from 101 V nominal. Also, equipment designed for 220 V to 240 V nominals is not intended for operation from 202 V or 250 V nominals. In these cases, a step-up or step-down transformer (depending on voltage source) should be used. Without transformers, system availability and equipment operation is affected.

5.19 EFFECTS OF DIRECT CURRENT IN AC INPUT POWER CIRCUITS

Input ac power circuits can contain direct current components due to asymmetric loading with respect to voltage polarity (for example, half-wave power rectification; dissimilar components in an otherwise symmetrical circuit; half-wave control or measurement rectification; unequal phase angle commutation; or unbalanced component characteristics).

In ac power distribution systems, direct currents can yield undesirable effects, including:

- Affecting the operation of current sensing devices, interfering with proper operation
- Causing saturation effects in magnetic elements, causing overheating, improper operation, and/or distorted source voltages
- Causing metal corrosion in the presence of electrolytic environmental conditions

The direct current attributed solely to the effect of component tolerance mismatch on a symmetrically configured load is presumed to cancel out when there are a large number of products on a site and therefore are not disturbing ac power sources.

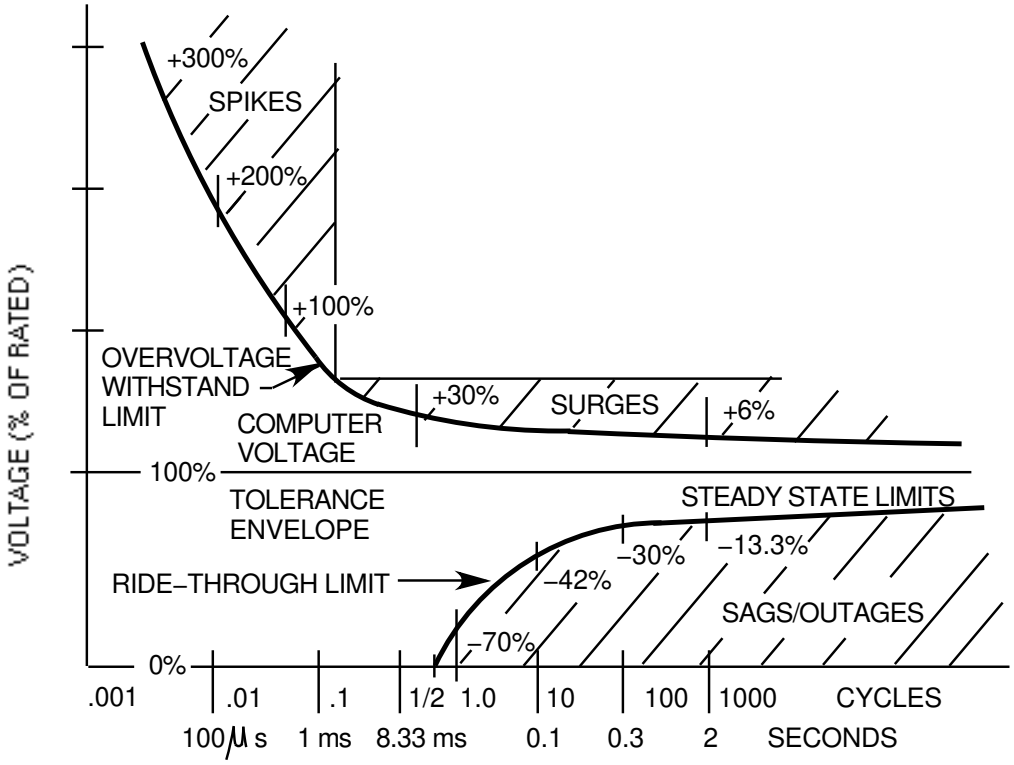
To minimize the effects of direct current, observe the limitations given in subhead 4.16. Additional practices that can mitigate the effects of direct current include:

- Related products (those that are frequently used together) should endeavor to produce opposing polarities of direct current, to cancel or reduce the net direct current in both neutral and phase lines.
- Multiphase configurations should not accumulate direct current in the neutral conductor, but should alternate the polarity of current from line to neutral.

5.20 COMPUTER VOLTAGE SUSCEPTIBILITY PROFILE

Figure 6 illustrates the computer voltage susceptibility envelope. It is a composite of data obtained from various computer manufacturers and is not to be interpreted as a specification to be met by any product or system. It is presented here to indicate the major troublesome areas of voltage disturbances to computer systems.

Figure 6: Disturbance/Time-Duration Computer Susceptibility Profile (Information from CBEMA ESC-3 Power Interface Subcommittee, 1978)



Line voltage spikes are primarily applied to front-end components and power conversion devices. Depending on the severity of the spike (peak amplitude, waveform) and its frequency of occurrence, degradation of insulation properties may result as well as component damage. Voltage impulses also find paths through stray capacitance and magnetic induction. Although these impulses may be attenuated, sufficient energy may be coupled into high impedance circuits and cause a signal transition of logic levels when one was not intended.

Overvoltage surges are applied directly to front-end components of power conversion devices and other ac components; they may cause overvoltage stress with the subsequent result of early component failure or damage. These surges may also be sufficiently high to cause the regulated dc supply voltages to logic and memory to exceed limits with

subsequent changes in threshold levels of digital signals. Momentary sags or outages of sufficient duration will result in the computer initiating its shutdown routine. In this case, battery backup may be used to extend computer operation of critical circuits.

The boundary of the sag and outage profile is referred as the ride-through limit and the boundary of the spike and surge profile is referred to as the overvoltage withstand limit. The area bounded by the ride-through and overvoltage withstand limit is referred to as the system performance survival area to power line disturbances.

5.21 VOLTAGE WAVEFORM DISTORTION

Voltage waveform distortion is caused by devices that change the shape of the nominal sine wave of the voltage in synchronism with the line frequency. The distorted wave is made up of fundamental and harmonics of various frequencies and magnitudes.

The harmonic content and magnitude existing in any power system is largely unpredictable. The effects will vary widely in various parts of the system due to the effect of different frequencies. Because the distorted wave is in the supply system, harmonic effects may occur at any point on the system where the distorted wave exists. This is not limited to the immediate vicinity of the harmonic-producing device. Where power is converted to direct current or some other frequency, harmonics will exist in a distorted alternating component of the converted power. Harmonics may be transferred from one circuit or system to another by direct connection or by inductive or capacitive coupling. Because these harmonics are in the low-frequency audio range, objectionable interference may be caused in communication circuits. In addition, these harmonics may cause errors in meter readings, and may cause differential switches, such as ground current monitors and circuits, to operate incorrectly.

Whether recognized or not, all waveform distortion causes increased operating costs by increasing:

a. Losses in transformers, motors, capacitors, conductors, and switch gear

b. Maintenance

c. Utility bills

Over the past several years, many countries have addressed these issues. To avoid each country establishing its own rules and causing an impediment to trade, IEC Publication 555, *Disturbances in Supply Systems Caused by Household and Similar Electrical Equipment* was approved by the majority of countries.

The IEC document applies to all household appliances and similar equipment using electronics capable of causing waveform distortions and designed for direct connections to nominal voltage of 220 V, 240 V, 220 V to 380 V, or 240 V to 415 V.

At the present time, there are no similar standards for 60 Hz countries, such as the U.S. and Canada.

Computer equipment intended for marketing in the European countries may be required to meet the following requirements in the future. The harmonics of the input current shall be such that if the equipment were to be connected to the artificial network of Figure 1 and supplied at nominal voltage, the resulting harmonic content of the current in the artificial network would be equal to or less than the following values:

Table 7: Input Current Harmonics

Harmonic Order (n)	Maximum Harmonic Current(A)
Odd	Amperes
3	2.30
5	1.14
7	0.77
9	0.40
11	0.33
13	0.21
$15 \leq n \leq 39$	0.15 x 15/n
Even	Amperes
2	1.08
4	0.43
6	0.30
$8 \leq n \leq 40$	0.23 x 8/n

NOTE TO TABLE 8

Numbers in parentheses refer to notes at the end of the table. Letters in parentheses refer to figures in subhead 5.1.

Table 8: AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Afghanistan	50	380/220(A) 220(L)	380/220(A)	380/220(A)	(7)
Algeria	50 ±1.5	220/127(E) 220(L)(1)	380/220(A) 220/127(A)	380/220(A)	±5 and ±10
Angola	50	220(L)(1)	380/220(A)	380/220(A)	(7)
Anguilla	50	230(L)(1)	400/230(A)	400/230(A)	(7)
Antigua	60	230(L)(1)	400/230(A)	400/230(A)	(7)
Argentina	50 ±1.0	225(L)(1) 220(L)(1)	390/225(A) 220(L) 380/220(A)	390/225(A) 380/220(A)	±10
Australia (East) (5)	50 ±0.5	415/240(A)(E) 240(L)	415/240(A)	415/240(A)	±6 (6)
Australia (West) (5)	50 ±0.5	440/250(A)(E) 250 (L)	440/250(A)	440/250(A)	±6 (6)
Austria	50 ±0.1	380/220(A)(B) 220(L)	380/220(A) 220(L)	380/220(A)	± 5
Bahamas	60	240/120(G) 120(L)	240/120(G) 120(L)	415/240(A) 208/120(A)	(7)
Bahrain	50 and 60	400/230(A) 230(L) 110(L)	400/230(A) 380/220(A) 230(L) 220/110(K)	400/230(A) 380/220(A)	± 6
Bangladesh	50 ±4	400/230(A) 230(L)	400/230(A)	400/230(A)	±5
Barbados	50 ± 0.4	230/115(G)(K) 200/115(A)(E)	230/115(G)(K) 200/115(A)(E)	230/115(G) 200/115(A)	

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Belgium	50 ±3	380/220(A) 220/127 (A) 220 (F)	380/220(A) 220/127(A) 220 (F)	380/220 (A) 220/127(A) 220 (F)	± 5 day, ±10 night
Belize	60 ± 0.1	220/110(K)	220/110(K)	440/220(K)	(7)
Bermuda	60 ±0.1	240/120(K) 208/120(A)	240/120(K) 208/120(A)	208/120(A) 240/120(K)	±5
Bolivia	50 ±1	230/115 (H)	230/115 (H)	230/115 (H)	± 5
Botswana	50	220(L)(1)	380/220(A)	380/220(A)	(7)
Brazil	60	220 (L)(1) 127 (L)(1)	380/220(A) 220/127 (A)	380/220(A) 220/127(A)	(7)
Bulgaria	50 ±0.1	380/220(A) 220 (L)	380/220(A) 220 (L)	380/220 (A)	±5
Burma	50	230 (L) (1)	400/230(A) 230 (L)	400/230(A)	(7)
Cambodia	50	208/120(A) 120(L)	380/220(A) 208/120(A)	380/220(A) 208/120(A)	(7)
Cameroon (FR)	50 ± 2	220(L)(1)	380/220(A)	380/220(A)	± 5
Canada	60 ±0.02	240/120(K)	480 (F) 240 (F) 240/120(K) 208/120(A)	208/120(A) 600 (F) 480 (F) 240 (F)	+4, -8.3
Cayman Islands	60 ±0.1	240/120 (K)	240/120(K)(G)	480/240(G) 480/277(A) 240/120(G) 208/120(A)	±10
Chad	50	220(L)(1)	220(L)(1)	380/220(A)	(7)
Chile	50	220(L)(1)	380/220(A)(1)	380/220(A)	(7)
China (PR)	50	220(L)(1)	380/220(A)	380/220(A)	±7

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Colombia	60 ±1	240/120(G) 120(L)	240/120(G) 120(L)	240/120(G)	±10
Commonwealth of Independent States (formerly USSR)	50	380/220(A) 220(L) 220/127(A) 127(L)	380/220(A) 220(L)	380/220(A)	(7)
Costa Rica	60	120(L)(1)	240/120(K) 120(L)(1)	240/120(G)	(7)
Cyprus	50 ±2.5	240(L)(1)	240(L)(1)	415/240(A)	±6
Czechoslovakia	50 ±0.1	380/220(A) 220(L)	380/220(A) 220(L)	380/220(A)	±10
Dahomey	50 ±1	380/220(A) 220(L)	380/220(A) 220(L)	380/220(A)	±10
Denmark	50 ±0.4	380/220(A) 220(L)	380/220(A) 220(L)	380/220(A)	±10
Dominica	50	230(L)(1)	400/230(A)	400/230(A)	(7)
Dominican Republic	60	110(L)(1)	220/110(K)(1) 110(L)	220/110(G)	(7)
Ecuador	60	127(L)(1) 120(L)(1) 110(L)	240/120(K) 208/120(A) 220/127(A) 220/110(K)	240/120(K) 208/120(A) 220/127(A) 220/110(K)	(7)
Egypt (AR)	50 ±1	380/220(A) 220(L)	380/220(A) 220(L)	380/220(A)	±10
El Salvador	60±1	240/120(K)	240/120(K)(G)	240/120(G)	±5
Ethiopia	50	220(L)(1)	380/220(A)	380/220(A)	(7)
Falkland Islands	50 ±3	230(L)(1)	400/230(A)	400/230(A)	±2.5

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Fiji Isles	50 ±1	415/240(A) 240(L)	415/240(A) 240(L)	415/240(A)	(7)
Finland	50 ± 0.1	220(L)(1)	380/220(A)	500(B) 380/220(A)(D) 660/380(A)	± 10
France	50 ±1	380/220(A) 220(L) 220/127(E) 127(L)	380/220(A)(D) 380(B)	380(B) 380/220(A)(D)	±10
Gambia	50	230(A)(1)	230(A)(1)	400/230(A)	±5(1)
Germany	50 ± 0.3	380/220(A) 220(L) 220/127(A) 127(L)	380/220(A) 220(L)	380/220(A) 660/380(A)	± 10
Ghana	50 ±5	250 (L)(1)	250(L)(1)	440/250(A)	±10
Gibraltar	50 ±1	415/240(A)	415/240(A)	415/240(A)	±6
Greece	50 ±1	220(L)(1)	380/220(A)	380/220(A)	±5
Grenada	50	230(L)(1)	400/230(A)	400/230(A)	(7)
Guadeloupe	50 and 60	220(L)(1)	380/220(A)	380/220(A)	(7)
Guam (Mariana Island)	60 ±1	240/120(K) 208/120(A) 240(L) 120(L)	240/120(K) 208/120(A)	480/277(A) 480(D) 240/120(H) 208/120(A)	+8, -10
Guatemala	60 ±1.7	240/120(K)	240/120(K)	240/120(G)	±10
Haiti	60	230(L)(1) 220(L)(1) 115(L)	380/220(A) 230/115(K) 220(L)	380/220(A) 230/115(G)	(7)
Honduras	60	110(L)	220/110(L) 110(L)	220/110(K)	(7)

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Hong Kong (and Kowloon)	50 ±2	346/200(A) 200(L)	346/200(A) 380/220(A) 200(L)(1)	346/200(A) 380/220(A)	±6
Hungary	50 ±2	380/220(A) 220(L)	380/220(A) 220(L)	380/220(A)	+5, -10
Iceland	50 ±0.1	380/220(A) 220(L)	380/220(A) 220(L)	380/220(A)	(7)
INDIA (2)					
Bombay	50 ±1	440/250(A) 230(L)	440/250(A) 230(L)	440/250(A)	±4
New Delhi	50 ±3	400/230(A) 230(L)	400/230(A) 230(L)	400/230(A)	±6
Ramkrishnapuram	50 ±3	400/230(A) 230(L)	400/230(A) 230(L)	(7)	±6
Indonesia	50 +1, -2	220/127(A)	380/220(A) 220/127(A)	380/220(A)	±5
Iran	50 ± 5	220(L)(1)	380/220(A)	400/230(A) 380/220(A)	±15
Iraq	50	220(L)(1)	380/220(A)	380/220(A)	±5
Ireland, Northern	50 ±0.4	230(L)(1) 220(L)(1)	400/230(A) 380/220(A)	400/230(A) 380/220(A)	±6
Ireland, Republic of	50	220(L)(1)	380/220(A)	380/220(A)	(7)
Israel	50 ±0.2	400/230(A) 230(L)	400/230(A) 230(L)	400/230(A)	±6
Italy	50 ±0.4	380/220(A) 220/127 (E) 220(L)	380/220(A) 220/127 (E)	380/220(A) 220(C)	±5 (urban) ±10(rural)
Ivory Coast	50	220(L)(1)	380/220(A)	380/220(A)	(7)

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Jamaica	50 ±1	220/110(G)(K)	220/110(G)(K)	220/110(G)	±6
Japan (East)	50 ±0.2 (3)	202/101(K) 101(L)	202/101(H)(K)	202/101(H) 202(G)(J)	±10
Japan (West)	60 ±0.1 (3)	210/105(K) 202/101(K) 101(L)	210/105(H)(K) 202/101(K) 101(L)	210/105(H) 202/101(H)	±10
Jordan	50	380/220(A) 220(L)	380/220(A)	380/220(A)	(7)
Kenya	50	240(L)(1)	415/240(A)	415/240(A)	(7)
Korea, North	60 +0, -5	220(L)	380/220(A)	380/220(A)	+6.8, -13.6
Korea, South	60	100(L)	200/100(K)	(7)	(7)
Kuwait	50	240(L)(1)	415/240(A)	415/240(A)	(7)
Laos	50±8	380/220(A)	380/220(A)	380/220(A)	±6
Lebanon	50	220(L)(1) 110(L)(1)	380/220(A) 220(L) 190/110(A) 110(L)	380/220(A) 190/110(A)	(7)
Lesotho	50	220(L)(1)	380/220(A)	380/220(A)	(7)
Liberia	60 ±3.3	240/120(K)	240/120(K)	415/240(B) 240/120(K) 208/120(D)	(7)
Libya	50	230(L)(1) 127(L)(1)	400/230(A) 220/127(A) 230(L) 127(L)	400/230(A) 220/127(A)	(7)
Luxembourg	50 ±0.5	380/220(A) 220/127(A) 208/120(A)	380/220(A) 220/127(A) 208/120(A)	380/220(A) 220/127(A)	±5 and ±10

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Malagasy Republic	50 ±2	220(L)(1) 127(L)(1)	380/220(A) 220/127(A)	380/220(A) 220/127(A)	±3
Malawi	50	230(L)(1)	400/230(A)	400/230(A)	(7)
Malaysia	50 ±1.0	240(L)(1)	415/240(A)	415/240(A)	+5, -10
Mali	50	220(L)(1) 127(L)(1)	380/220(A) 220/127(A) 220(L) 127(L)	380/220(A) 220/127(A)	(7)
Malta	50 ±1	240(L)(1)	415/240(A)	415/240(A)	(7)
Martinique	50	127(L)(1)	220/127(A) 127(L)	220/127(A)	(7)
Mauritius	50 ±1.0	230(L)(1)	400/230(A)	400/230(A)	±6
Mexico	60 ±0.2	220/127(A) 220(L) 120(M)	220/127(A) 220(L) 120(M)	480/277(A) 220/127(B)	±6
Monaco	50	380/220(A) 220(L) 220/127(A) 127(L)	380/220(A) 220(L)	380/220(A)	(7)
Montserrat	60	230(L)(1)	400/230(A)	400/230(A)	(7)
Morocco	50	220/127(A) 200/115(A)	380/220(A)	380/220(A)	(7)
Nepal	50 ±1	220(L)(1)	400/220(A) 220(L)	400/220(A)	±10
Netherlands	50 ±0.4	380/220(A) 220(E)(L)	380/220(A)	380/220(A)	±6
Netherlands Antilles	50 and 60	220(L)(1) 127(L)(1) 120(L)(1) 115(L)(1)	380/220(A) 230/115(K) 220/127(A) 208/120(A)	380/220(A) 230/115(G) 220/127(A) 208/120(A)	(7)

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
New Guinea	50 ±2	240(L)(1)	415/240(A) 240(L)	415/240(A)	±5
New Zealand	50 ±1.5	400/230(A)(E) 230(L) 240(L)	415/240(A)(E) 400/230(A)(E) 230(L) 240(L)	400/230(A) 415/240(A)	±5
Nicaragua	60	240/120(G)(K)	240/120(G)(K)	240/120(G)	(7)
Nigeria	50 ±1	230(L)(1) 220(L)(1)	400/230(A) 380/220(A)	400/230(A) 380/220(A)	±5
Niger	50 ±1	220(L)(1)	380/220(A)	380/220(A)	±2.5
Norway	50 ±0.2	230(B)	380/220(A) 230(B)	380/220(A) 230(B)	±10
Oman	50	240(L)(1)	415/240(A) 240(L)	415/240(A)	(7)
Pakistan	50	230(L)(1)	400/230(A) 230(L)	400/230(A)	(7)
Panama	60 ±0.17	240/120(K)	480/277(A) 240/120(K)	208/120(A) 480/277(A)	±5
Paraguay	50	220(L)(1)	440/220(K) 380/220(A)	440/220(G) 380/220(A)	(7)
Peru	60	225(B)(M)	225 (B)(M)	225(B)	(7)
PHILIPPINES (2)	60 ±0.16	220/110(K)	220/110(H)	440(B) 220/110(H)	±5
Manila (Metropolitan Area)	60 ±5	240/120(H)(K) 240/120(H)	240/120(H)(K) 240/120(H)	240/120(H)	±5
Poland	50 ±1	220(L)(1)	380/220(A)	380/220(A)	±5

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Portugal	50 ±1	380/220(A) 220(L)	380/220(A) 220(L)	380/220(A)	±5
Puerto Rico	60 ±10	240/120(L)	480(F) 240/120(L)	480(F)	±10
Qatar	50	240(L)(1)	415/240(A) 240(L)	415/240(A)	±6
Romania	50 ±1	220(L)(1)	380/220(L)	380/220(A)	±5
Rwanda	50 ±1	220(L)(1)	380/220(A)	380/220(A)	±5
Sabah	50 ±0.5	240(L)(1)	415/240(A)	415/240(A)	±6
Saudi Arabia	50 and 60 ± 0.5	220/127(A) 127(L)	380/220(A) 220/127(A)	380/220(A) 220/127(A)	±5
Senegal	50	127(L)(1)	220/127(A) 127(L)	220/127(A)	(7)
Sierra Leone	50	230(L)(1)	400/230(A) 230(L)	400/230(A)	(7)
Singapore	50 ±0.5	400/230(A) 230(L)	400/230(A)	400/230(A)	±3
Somali Republic	50	230(L) 220(L) 110(L)(1)	440/220(K) 220/110(K) 230(L)	440/220(G) 220/110(G)	(7)
South Africa	50 ± 2.5	433/250(A)(4) 400/230(A)(4) 380/220(A) 220(L)	433/250(A)(4) 400/230(A)(4) 380/220(A)	380/220(A) 500(B)	±5
Spain	50 ±3	380/220(A)(E) 220(L) 220/127(A)(E) 127(L)	380/220(A) 220/127(A)	380/220(A)	±7

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Sri Lanka	50 ±2	230(L)(1)	400/230(A) 230(L)	400/230(A)	±6
St. Kitts & Nevis	60	230(L)(1)	400/230(A)	400/230(A)	(7)
St. Lucia	50	240(L)(1)	415/240(A)	415/240(A)	(7)
St. Vincent	50	230(L)(1)	400/230(A)	400/230(A)	(7)
Sudan	50	240(L)(1)	415/240(A) 240(L)	415/240(A)	(7)
Surinam	50 & 60	115(L) 127(L)(1)	230/115(K) 220/127(A) 220/110(K)	230/115(G) 220/127(A) 220/110(G)	(7)
Swaziland	50 ±2.5	230(L)(1)	400/230(A) 230(L)	400/230(A)	±6
Sweden	50 ±0.2	380/220(A) 220(L)	380/220(A) 220(L)	380/220(A)	±10
Switzerland	50 ±0.5	380/220(A) 220(L)	380/220(L) 220(L)	380/220(A)	±10
Syria	50	220(L)(1) 115(L)(1)	380/220(A) 220(L) 200/115(A) 115(L)	380/220(A) 200/115(A)	(7)
Taiwan	60 ±4	380/220(A) 220(L) 220/110(K) 110(L)	380/220(A) 220/110(H)	380/220(A) 220(H)	±5 and ±10
Tanzania	50	400/230(A)	400/230(A)	400/230(A)	(7)
Thailand	50	220(L)(1)	380/220(A) 220(L)	380/220(A)	(7)
Togo	50	220(L)(1)	380/220(A)	380/220(A)	(7)

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Tonga	50	415/240(A) 240(L) 110(L)	415/240(A) 240(L) 110(L)	415/240(A)	(7)
Trindad and Tobago	60 ±0.5	230/115(K)	400/230(A) 230/115(G)	400/230(A)	±6
Tunisia	50 ±2	380/220(A) 220(L)	380/220(A) 220(L)	380/220(A)	±10
Turkey	50 ±2	220(L)(1)	380/220(A)	380/220(A)	±10
Uganda	50 ±0.1	240(L)(1)	415/240(A)	415/240(A)	± 4.5
UNITED ARAB EMIRATES (2)					
Dubai	50 ±0.5	220(L)(1)	380/220(A) 220(L)	380/220(A)	±2 and ±3
Ajman	50	230(L)(1)	400/230(A)	(7)	(7)
Abu Dhabi	50	415/240(A)	415/240(A)	415/240(A)	(7)
United Kingdom (excluding N. Ireland)	50 ±1	240(L)(1)	415/240(A)	415/240(A)	±6
Uruguay	50 ±1	220(B)(L)	220(B)(L)	220(B)	±6
USA (2)					
Charlotte (North Carolina)	60 ±0.3	240/120(K) 208/120(A)	460/265(A) 240/120(K) 208/120(A)	460(F) 240(F) 460/265(A) 240/120(K) 208/120(A)	+5, -2.5
Detroit (Michigan)	60 ±0.3	240/120(K) 208/120(A)	480(F) 240/120(H) 208/120(A)	480(F) 240/120(H) 208/120(A)	+4, -6.6

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Los Angeles (California)	60 0.3	240/120(K)	240/120(G) 208/120(A)	240/120(G) 208/120(A)	±5
Miami (Florida)	60 ±0.3	240/120(K) 208/120(A)	240/120(G) 240/120(H) 208/120(A)	480/277(A) 240/120(H)	±5
New York (New York)	60 ±0.3	240/120(K) 208/120(A)	240/120(K) 208/120(A) 240(F)	480/277(A) 480(F)	±5
Pittsburgh (Pennsylvania)	60 ±0.3	240/120(K)	460/265(A) 240/120(K) 208/120(A) 460(F) 230(F)	460/265(A) 208/120(A) 460(F) 230(F)	±5 (lighting) ±10(power)
Portland (Oregon)	60 ±0.3	240/120(K)	480/277(A) 240/120(K) 208/120(A) 480(F) 240(F)	480/277(A) 208/120(A) 480(F) 240(F)	±5
San Francisco (California)	60 ±0.3	240/120(K)	480/277(A) 240/120(K) 208/120(A)	480/277(A) 240/120 (G) 208/120(A)	±5
Toledo (Ohio)	60 ±0.3	240/120(K) 208/120(A)	480/277(C) 240/120(H) 208/120(A)	480(F) 480/277(A) 208/120(A)	±5
Venezuela	60	240/120(G) 208/120(A)	240/120(G) 208/120(A)	240/120(G) 208/120(A)	(7)
Viet Nam	50 ±0.1	220(L)(1) 120(L)(1)	380/220(A) 208/120(A)	380/220(A)	±10
Independent State of Western Samoa	50	400/230	(7)	(7)	(7)
Yemen	50 ± 1	250(L)(1)	440/250(A)	440/250(A)	± 4
Yugoslavia	50	380/220(A) 220(L)	380/220(A) 220(L)	380/220(A)	(7)

Table 8 (Cont.): AC Power Characteristics of Various Countries and Market Areas

Country	Frequency Hz Tolerance %	Household Voltage V	Commercial Voltage V	Industrial Voltage V	Voltage Tolerance %
Zaire	50	220(L)(1)	380/220(A)	380/220(A)	(7)
Zambia	50 ±2.5	230(L)(1)	400/230(A)	400/230(A)	± 3.75
Zimbabwe	50 ±2.5	225(L)(1)	390/225(A)	390/225(A)	±6.6

NOTES TO TABLE 8

1. **The supply to each house is normally single-phased, using 1-phase line and neutral of systems(A) or (G).**
2. **More than one area of country has been given to illustrate the differences which exist. These may not be the only supplies available.**
3. **Frequency is 50 Hz (eastern area) and 60 Hz (western area). Dividing line is a North/South line through Shizuoka on Honshu Island.**
4. **Only a few towns have this supply.**
5. **The nominal voltage in Western Australia is 250 V, whereas all other states employ a nominal voltage of 240 V.**
6. **Under fault conditions on the supply grid (that is, where a rerouting of the supply has to be undertaken as a temporary measure to back up loss of supply in one area), the voltage tolerances are relaxed to +10% on the 240 V nominal supply and +6, -10% on the 250 V nominal.**
7. **Information not available at the time of this printing.**

APPENDIX A REFERENCED DOCUMENTS

A.1 EL-Class Digital Documents

EL-Class Number	Document Title
EL-00002-00	*DEC STD 002-0 AC Power Wiring, Safety Earth Grounding, Plugs and Receptacle Information and Requirements*
EL-00066-02	*DEC STD 066-2 Waivers to Digital Design Standards*
EL-00080-01	*DEC STD 080-1 Digital Product Safety Industrial Control Equipment - Design Criteria*
EL-00119-01	*DEC STD 119-1 Digital Product Safety — Design Criteria*
EL-00122-01	*DEC STD 122-1 AC Power Line Standard - Measurement of AC Power Parameters*
EL-00186-00	*DEC STD 186-0 Signal Integrity*

Use VTX SMC to order copies of EL-class documents from Standards and Methods Control. Send distribution questions to JOKUR::SMC or call DTN: 234-4423.

A.2 Other Documents

Document Number	Document Title
ANSI/IEEE C62.41	*ANSI/IEEE C62.41-1991, IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits*
IEC PUBLICATION 555	*Disturbances in Supply Systems Caused by Household Appliances and Similar Electrical Equipment*

A.3 Ordering Information

Following are the sources for documents not available from Standards and Methods Control.

- American National Standards Institute (ANSI)
  1430 Broadway, New York, NY 10018
  Telephone (212) 354-3300 x479
- Institute of Electrical and Electronic Engineers, Inc. (IEEE)
  445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855
  Telephone 1-800-678-4333

```
+---------------------------------------------------------------------+
|                        READER COMMENTS                              |
|                                                                     |
| Your  comments  and suggestions  will help  Standards and Methods   |
| Control improve their services and documents.                       |
+---------------------------------------------------------------------+
```

Did you request this document? _____ If so, did it arrive within a satisfactory period of time? _____ Please comment.

What are your impressions of this document? Consider format, organization, completeness, readability, and illustrations.

————————————**FOLD ON THIS LINE**———————————————————————— -

Did you find technical or clerical errors in this document? If so, please specify the page number(s) and the error(s).

Are the instructions for the update package clear? _____
Was an index available? _____ If not, is one needed? _____
Do you have other suggestions for improving this document?

The following information is optional:

Name _____ Mailstop _____

Department _____ Node _____

Send your comments to JOKUR::PROJECTS, or fold, staple, and send this page through interoffice mail to:

```
+------------------------------+
|       READERS' COMMENTS      |
| STANDARDS AND METHODS CONTROL |
|           NRO4/D4            |
+------------------------------+
```